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OPTICAL DESIGN FOR A BALLOON-BORNE MAGNETOGRAPH

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16. Abstract

This report details activities performed in order to accomplish the optical design of a balloon-borne solar vector magnetograph.

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1. Introduction

This report documents the optical design tasks accomplished at UAH in support of the NASA/MSFC-led development of a balloon-borne solar vector magnetograph. The work was performed in the Center for Applied Optics' Optical Design Lab. The objectives of this effort are described first, followed by a detailed breakdown of the accomplishments under each task.

The first task was to analyze the optical design of the Experimental Vector Magnetograph (EXVM) to be provided by NASA/MSFC ES52. This ground-based system, to be used as a test-bed for new magnetograph technologies, was designed by a separate team using the CODE V optical design code from Optical Research Associates. The design was to be input into the SYNOPSYS optical design program from Breault Research Organization, Inc. and the resultant performance determined. The results would be used to confirm the performance specifications of the EXVM. Any source of discrepancy between this and previous analyses would be traced and documented.

Next, a first-order layout of the optical system for a balloon-borne solar vector magnetograph (BVM) would be developed to establish minimum packaging requirements and first-order design parameters. The design would meet balloon compatibility and length and weight specifications as provided by ES52. The design would be flexible enough to handle a Cassegrain entrance aperture between 30 and 60 cm in diameter.

Following maturation of the instrument concept and results of lessons learned from the EXVM, a final BVM optical design would be developed that would meet NASA-supplied performance requirements. The final design was to include complete specification of each optical element's radius, thickness, material, coating, and spacing. A performance analysis would be done based on this design to provide a measure of image quality, tolerancing, ghost imaging, vignetting, and transmission. An estimate of the cost for each optical element was also to be developed.

Lastly, the BVM optical design team was to work very closely with the UAH team performing the polarization analysis to insure that the instrument

would meet the stringent polarization requirements. This task was to be performed simultaneously with the final design task above. This would avoid the possibility of later redesign of the optical system due to unaccounted-for instrumental polarization.

2. EXVM Optical Design Analysis

Upon completion of the EXVM optical design by the Polarization and Lens Design group at UAH (under a separate contract), the CAO design team input the system into the SYNOPSYS code. SYNOPSYS was utilized to give a new and separate evaluation of the design that was originally developed on CODE V. The design, when input exactly as given, yielded a performance identical to that predicted by CODE V (results of the SYNOPSYS analysis given in Appendix A). However, the polarimeter and filters, which contain calcite, quartz, and fused silica, had been modeled by the previous group simply as BK7. Also, the blocking filter was modeled with a thickness of 4 mm, not 9.5 mm as listed in the ES52 information. After inputing the real materials (available in SYNOPSYS) as appropriate and changing the blocking filter thickness, the performance was quite different (up to 2 waves of aberration). Nevertheless, since none of the affected components had any power, only a re-optimization of the air spaces was required to restore the near diffraction-limited performance. Another small problem that was discovered was that the maximum ray angles through the Fabry-Perot filter were within specification only to first order. A real ray trace indicated that higher ray angles were produced at some field angles (up to 31.9 arcmin for the upper rim ray at full field). Again, the air spaces were changed to lower the real ray angles to 23 arcmin or less. The spacing changes required to account for the real indices and blocking filter thickness, and lower the Fabry-Perot ray angles for the EXVM are given in Table 1 below (details of optimized design given in Appendix B). These corrections should be easy to accomplish during assembly of the EXVM system.

In summary, the performance specifications of the EXVM optical design have been confirmed assuming the air spaces will be adjusted appropriately during assembly.

Air Space Between ...	Original (mm)	Optimum (mm)	Difference (mm)
Polarimeter & Collimating Lens	315.00	320.40	+5.40
2nd Fold Mirror & Telecentric Lens	47.02	37.77	-9.25
Telecentric Lens & Fabry-Perot	220.23	156.99	-63.24
Last Imaging Lens & Field Lens	274.65	277.20	+2.55

TABLE 1. Spacing changes for optimum EXVM performance.

3. First-order Layout of BVM

The baseline solar magnetograph was understood to have the following key components: (1) a symmetrical Cassegrain telescope with a heat-rejecting, full-aperture pre-filter, (2) a high-sensitivity polarimeter, (3) a correlation tracker for accurate pointing, (4) a high-resolution spectral filter of either the Fabry-Perot or birefringent (Lyot) type, and (5) a large CCD array (2048 x 1024) imaging area. The imaging area would consist of either a single, large format CCD or a set of four, smaller CCDs with an image splitter. The full field of view was to be 4.3 x 8.6 arcmin (giving a diagonal half-angle FOV of 4.8 arcmin). With an image height of 22 mm (set by the detector array size), the overall system focal length would nominally be 15,756 mm. Primary mirror diameters of 305 mm (12") as well as 610 mm (24") were to be considered, yielding F/52 and F/26 systems, respectively. The primary operating wavelength was to be 5250 Å.

Due to its excellent performance and relatively low cost (through the use of off-the-shelf optical elements), the EXVM design was used as a starting point for the first-order layout of the BVM. From this starting point, the length and weight would be optimized for a balloon platform and the optical train configured for both 30 and 60 cm diameter primary telescope apertures. Specific length and weight requirements were not fully developed at the time by the NASA team, so the goal was simply to make the design as compact and light as reasonably possible while still meeting the performance requirements. Several assumptions were made about the various required elements of the BVM system based on the elements used in the operational MSFC magnetograph and those being procured for the EXVM. The 30 cm telescope,

polarimeter, correlation tracker, blocking filter, Fabry-Perot & birefringent filters, and the image splitter were all assumed to be identical to those to be used in the EXVM. Specific limitations assumed for some of these elements are listed in Table 2. Further assumptions made were: (1) the diameter of the Cassegrain secondary for the 60 cm system should be less than 33% of the primary diameter (to minimize mid-frequency MTF degradation), (2) the polarimeter should be at the front of the optical train (to minimize system-induced polarization errors), (3) the correlation tracker was to come before the blocking filter and have about half the image size of the main system, and (4) the blocking filter was to come before the Fabry-Perot filter.

Component	Aperture Diameter (mm)	Length (mm)	Collimated or Telecentric Space	Maximum Ray Angle
Polarimeter	25	93	Collimated	2°
Blocking Filter	46	9.5	N/A	That of EXVM
Fabry-Perot Filter 30 cm 60 cm	65 116	92 92	Telecentric Telecentric	23 arcmin 25 arcmin
Birefringent Filter	25	300	Either	1.3°

TABLE 2. Assumed specifications for BVM components.

With the guidelines thus established, four first-order layouts were developed with: (1) a 30 cm telescope and a Fabry-Perot filter, or 30F, (2) a 30 cm telescope and a birefringent filter, or 30B, (3) a 60 cm telescope and a Fabry-Perot filter, or 60F, and (4) a 60 cm telescope and a birefringent filter, or 60B. Four layouts were required since there was, as yet, insufficient information to make a final decision on either the telescope size or the filter type.

Again, using the EXVM as a starting point, the 30F layout was begun. First, the birefringent filter was removed from the EXVM design. In order to reduce the angles through the polarimeter, it was moved into the collimated space where the birefringent filter had been located. This will require a high quality, stress-free collimating lens. If one cannot be obtained, the polarimeter could be moved back in front of the collimating lens. The first fold mirror was then moved in to shorten the design since the polarimeter was much shorter than the birefringent filter. The locations of the Fabry-Perot and the lenses associated with it were adjusted slightly to reduce the ray angles through the

filter. Lastly, the field lens just before the image splitter was changed from a pair of doublets to a singlet. This would reduce the size, weight, and cost of the system with negligible impact on the image quality or color correction. Overall, this layout is still very similar to that of the EXVM. As with the EXVM, it has a slightly larger FOV (4.9 arcmin) than originally specified.

Next, the 30B system was layed out. It was decided to attempt to keep the differences between the Fabry-Perot and birefringent systems to a minimum in order to allow easier transition from one to another at a later date (even after parts had been procured). Thus, the birefringent filter was placed in the telecentric space where the Fabry-Perot had been in the 30F layout; everything up to the first telecentric lens was exactly the same. The four lenses surrounding the filter (2 before & 2 after) were altered to account for the differences in aperture and length between the birefringent filter and the Fabry-Perot. The field lens and image splitter remained the same as before. The first-order optical parameters still remain close to those of the EXVM with a 4.9 arcmin FOV.

The 60F layout was then developed. The first attempt was simply to double the aperture of the 30 cm telescope (without changing the surface shapes) and then adjust the other optics to account for the change in telescope F/#. The telescope, however, was no longer diffraction-limited across the entire field at this F/#. It also required the use of a very fast collimating lens to get the beam through the 25 mm diameter polarimeter. This would not be a good situation for either image quality or polarization control. Thus, a better-corrected telescope was used with a slightly higher F/# (longer focal length). This gave the desired performance across the field and made collimation easier. The polarimeter must remain behind the collimating lens in this case; it cannot be located ahead of it as in the EXVM. The rest of the layout was similar to the 30F design with larger lenses surrounding the Fabry-Perot. The telecentric relay lenses were also used to correct for the change in power of the telescope. Since the aperture of the Fabry-Perot was not quite double that of the 30 cm design, the FOV was reduced from 4.9 to 4.8 arcmin. A Y-Ybar diagram for this layout can be found in Appendix F. The field lens and image splitter still remained the same.

The 60B layout was the most difficult. As with the 30B system, the layout was kept the same as that for the 60F up to the first telecentric lens.

It was determined at this point, from first-order principles, that the beam could neither be completely telecentric nor completely collimated through the 300 mm long x 25 mm diameter birefringent filter. The only way to get the light through the filter without vignetting would be by placing the filter half-way between telecentric and collimated space (this gives the minimum cylindrical beam volume). There is no other alternative without a larger diameter filter (which was deemed very unlikely by the ES52 staff). While this is not optimum, it should produce a functional instrument. Also, the intermediate image formed in this case can be made to fall outside of the calcite filter if desired. Again, the lenses surrounding the filter are different from those of the 60F layout due to their new functions. The FOV was kept at 4.8 arcmin. A Y-Ybar diagram for this layout can be found in Appendix H. The field lens and image splitter are still the same.

The size of the layouts was minimized at slightly less than that of the EXVM for the 30 cm versions and slightly more than the EXVM for the 60 cm versions. The overall length of the 30 cm layouts was around 3 m with an approximate length and width of 1.6 m x 0.6 m. For the 60 cm layouts, the overall length was about 4 m with a length and width of about 2.4 m x 0.8 m.

And finally, at the request of ES52, a 2X converter option was added to the first-order layouts. A simple two-lens system was designed for insertion after the decollimating lens in each layout. This would double the magnification of the system in order to "zoom in" on special features of interest. The beam splitter for the correlation tracker could be placed either before or after the 2X converter to give either the normal or doubled magnification. This 2X converter is the same for all layouts.

4. Final Optical Design of BVM

The original plan for this stage of the effort was to accomplish a detailed final BVM optical design using one of the four layouts developed above based on the results of testing performed on an operational EXVM. This EXVM testing would help determine the proper combination of telescope and filter required to accomplish the BVM mission goals. However, EXVM testing results were not available during the time the final BVM design was being developed. Since no definitive decision could be made at that point, it was

decided to produce four separate final designs based on the four first-order layouts.

For each layout, specific lenses had to be selected and/or designed and the design optimized to meet the performance specifications. The required performance specification was for 0.5 arcsec resolution across the entire FOV in the wavelength band 5250 ± 10 Å. It was desired, however, to have diffraction-limited performance in all cases at 5250 Å as well as 6563 Å. These specifications were to apply both to the final image and the correlation tracker image. During optimization, the physical constraints which guided the first-order layouts (listed in Table 2 above) had to be carefully monitored to avoid being exceeded by the real rays. And lastly, the overall size of the designs had to be kept under control.

Each final design is explained in the paragraphs below. Specific details of each design can be found in the appendices at the back of the report. Each appendix includes the optical prescription, $1/10^{th}$-scale drawings, image analysis plots (transverse aberrations, OPD's, point-spreads, and MTF's), and the results of a tolerance analysis.

The final design of the 30F system (Figures 1 & 2 below and Appendix C) was very straightforward. The EXVM was designed with achromatic optics and was very nearly diffraction-limited (with the air-spaces optimized as stated in Table 1 above). Since this was the basis for the 30F first-order layout, very little had to be done to the design. The spacings were optimized for the slightly different layout and an off-the-shelf singlet was selected for the field lens. Thus, by using the remaining lenses as originally selected for the EXVM, no custom lenses are needed. The resultant image quality is slightly better than that of the EXVM, especially at full field. In other words, the design is now truly diffraction-limited. This is important as the diffraction-limited resolution of 0.44 arcsec (set by the wavelength of 5250 Å and aperture diameter of 304.8 mm) is just below the specified limit of 0.5 arcsec. The design is also well-corrected for color, as desired. There is no vignetting and the system should have an overall transmission very close to that of the EXVM. The ray angles remain within the appropriate limits. The 2X converter, also using off-the-shelf lenses, does not reduce image quality or violate any constraints when inserted. As for tolerances, the highest quality versions of the off-the-shelf lenses and fold mirrors should be adequate. The

30–CM SYSTEM WITH FABRY – PEROT FILTER

(EX1)

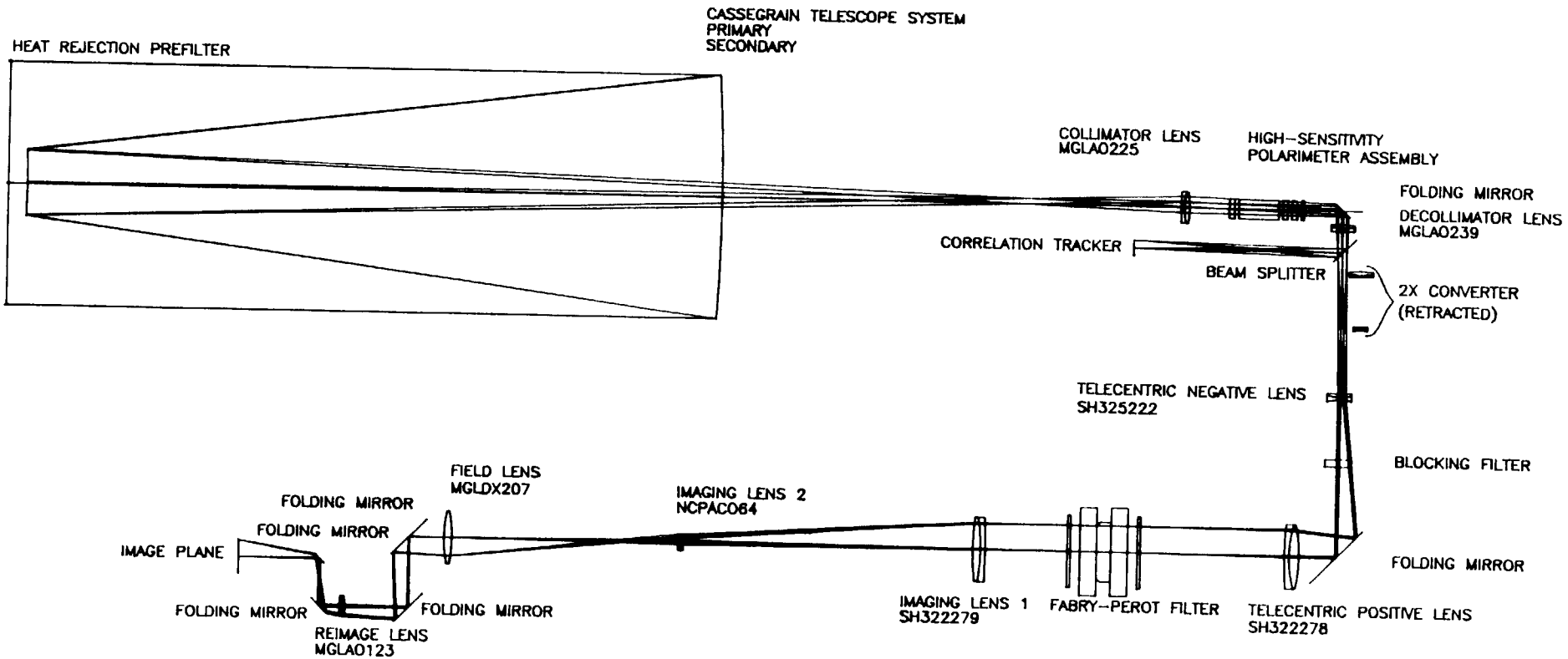

Fig. 1

30-CM SYSTEM WITH FABRY - PEROT FILTER & 2X CONVERTER

(EX1-2X)

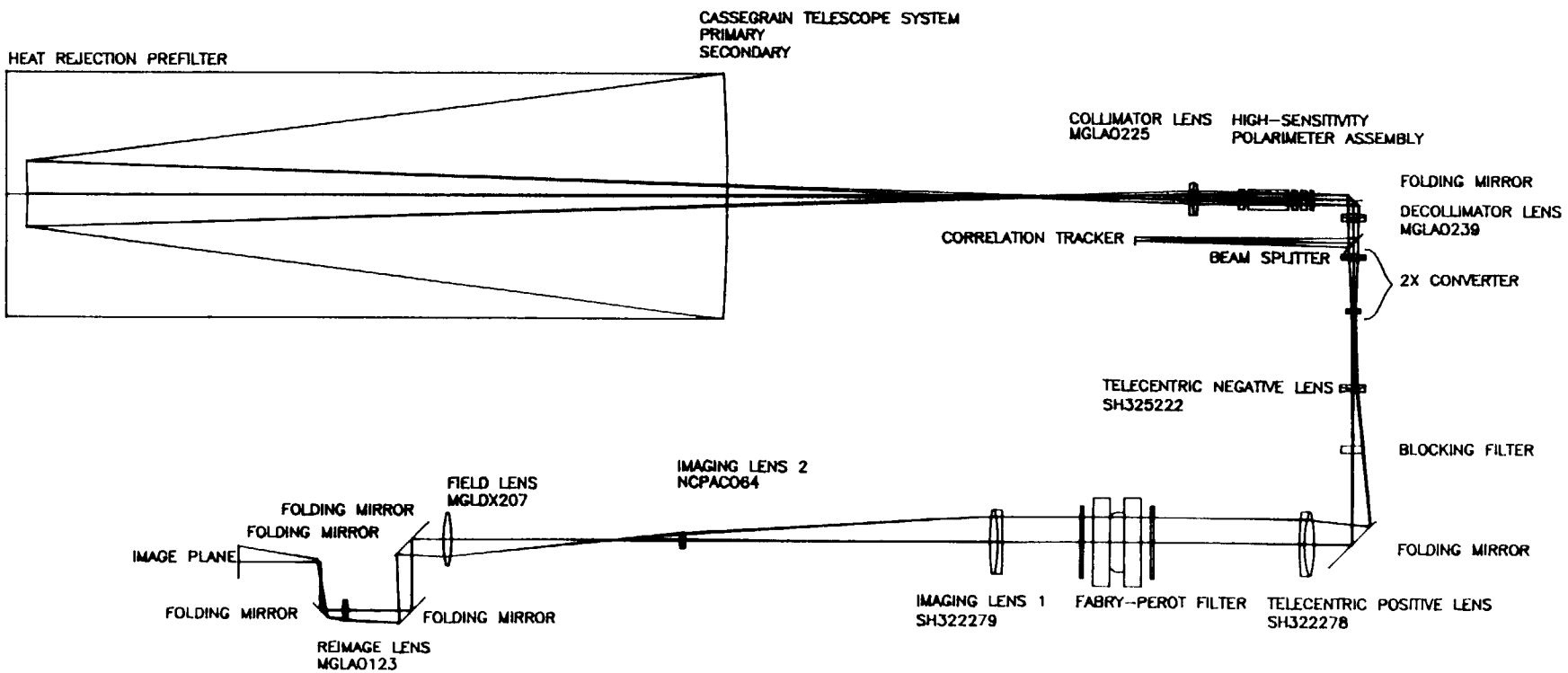

Fig. 2

telescope, polarimeter, and filters should be of the same quality used on the EXVM. This leaves the spacings to consider, and a tolerance analysis was performed on these. For the analysis, the wavefront error was allowed to degrade a maximum of 22.5%. This should still keep the OPD less than $\lambda/4$ as required. The resulting tolerances, as summarized at the end of the analysis in the appendix, are the amount of error for each particular spacing that would result in the maximum degradation. Generally, these tolerances should be divided by three to statistically account for errors throughout the system. The most sensitive spacings occur for the primary-to-secondary (around 1.7 μm), the secondary-to-collimating lens (27 μm), and the decollimating lens-to-negative lens (60 μm) air gaps. While the first tolerance is tight, it is within the state-of-the-art for current methods of optical system alignment. The other spacing tolerances are on the order of millimeters. The overall length is 3.4 m with the image splitter (slightly less than the EXVM), and the entire system should fit in an area 1.65 m x 0.68 m.

The final design of the 30B system (Figures 3 & 4 below and Appendix D) was slightly more involved. Since the front end was the same as for the 30F design, the new design started at the negative telecentric lens. Off-the-shelf lenses could not be found to produce the required telecentric beam through the 300 mm long filter, and new lenses were designed. These custom lenses are not overly complicated; they use only spherical surfaces and common glasses. The final imaging lens was also custom designed. The spacings were optimized using these lenses. At this point, the image splitter, which acts only as a one-to-one relay and is the same for all designs, was dropped from the analyses for simplification. The resultant image quality is slightly worse than that of the 30F system. It is still essentially diffraction-limited at 5250 Å but can not be totally color-corrected due to the long pathlength through the calcite filter. Refocussing could be performed at the longer wavelength to improve performance there. There is no vignetting and the system should have an overall transmission very close to that of the EXVM (when the birefringent filter is used with that system). The ray angles remain within the appropriate limits. The 2X converter, same design as before, does not reduce image quality or violate any constraints when inserted. The tolerances for the custom lenses should be standard for precision optics. The spacing tolerance analysis results are summarized at the end of the appendix. Again, these tolerances should be divided by three to give system values. The most sensitive spacing is still for the primary-to-secondary (around 1.4 μm).

30-CM SYSTEM WITH LYOT FILTER
(EB)

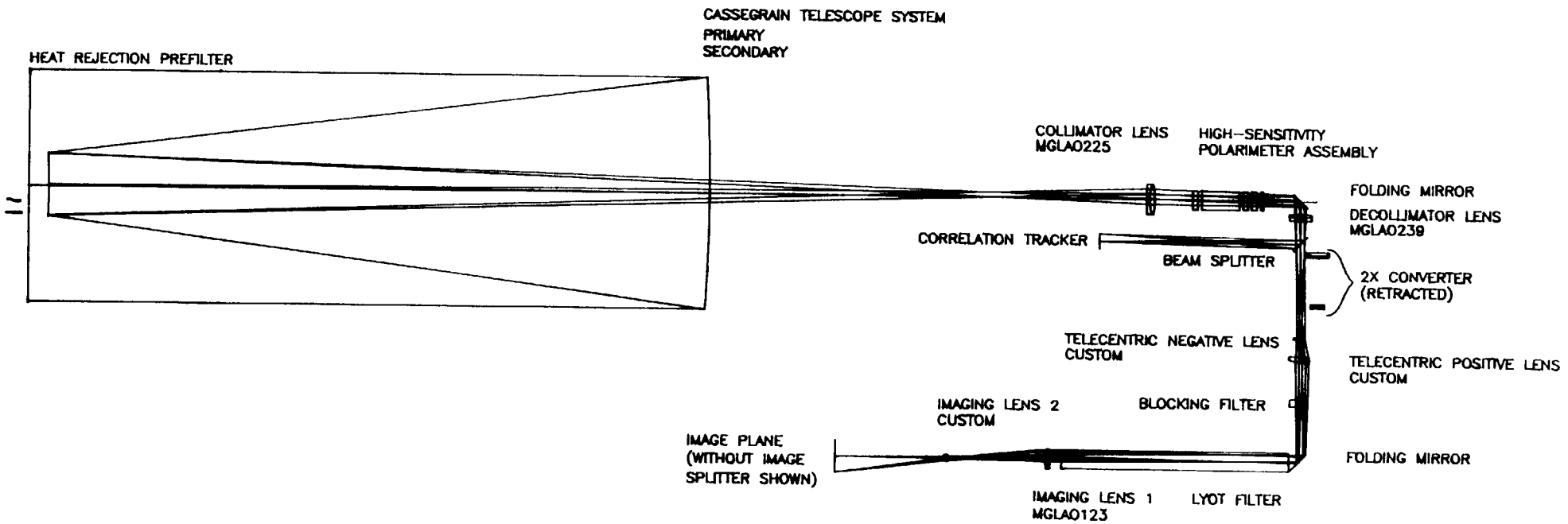

Fig. 3

30–CM SYSTEM WITH LYOT FILTER & 2X CONVERTER
(EB–2X)

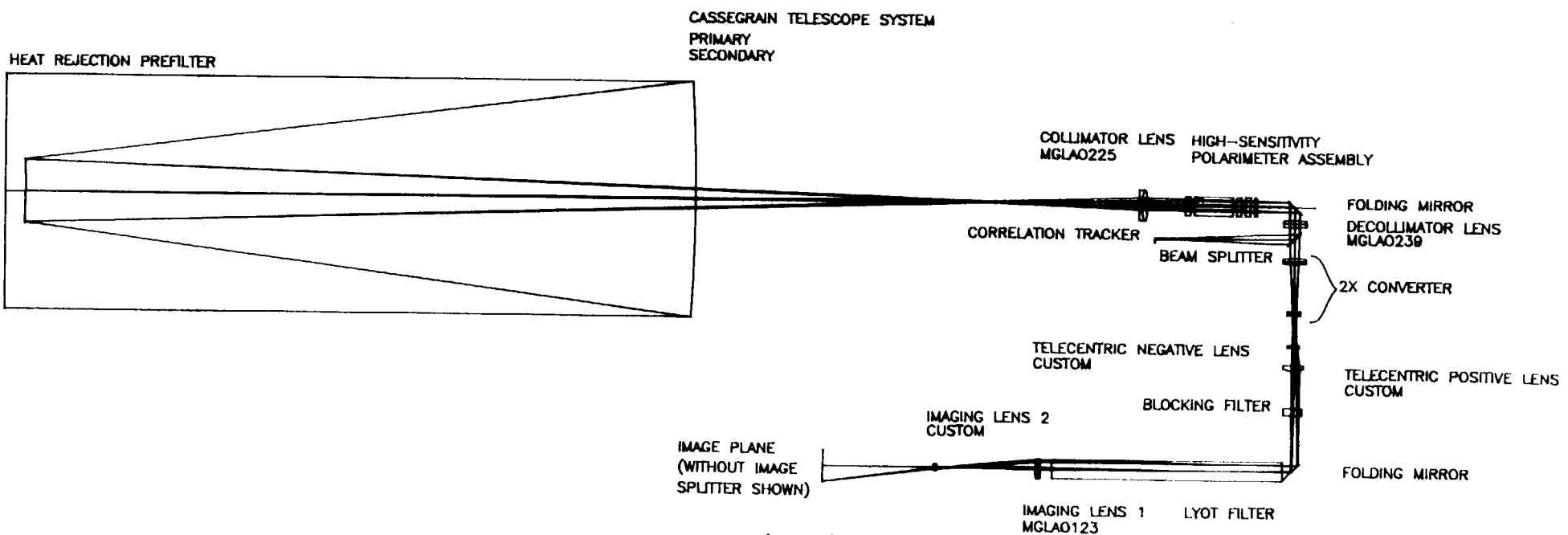

Fig. 4

The secondary-to-collimating lens (20 μm) and the decollimating lens-to-negative lens (50 μm) air gaps are still sensitive along with the negative telecentric-to-positive telecentric (8 μm) space. The remaining air gap tolerances are on the order of 100 μm. The overall length is shorter than before at 2.8 m with the image splitter (even though not shown), and the entire system should fit in an area 1.65 m x 0.53 m.

The correlation tracker image (Appendix E) is exactly the same for both of the 30 cm designs. It is diffraction-limited as desired with about half the size of the final image. As stated before, the correlation tracker beamsplitter can go before or after the 2X converter as desired.

Next came the final design of the 60F system (Figures 5 & 6 below and Appendix F). The telescope surfaces were optimized along with the collimating lens to meet the physical constraints of the polarimeter while maintaining good image quality. This required the use of some higher-order aspherics (6^{th}, 8^{th}, & 10^{th}) on the telescope. An off-the-shelf collimating lens could not be found, and a new lens was designed. The lenses surrounding the Fabry-Perot were also specially designed to give a total of three custom lenses. Again, the custom lenses were kept relatively simple. The spacings were optimized along with these lenses and three off-the-shelf lenses. The resultant image quality is diffraction-limited across the field. This gives twice the resolution of the 30 cm designs since the diffraction-limited resolution is now 0.22 arcsec at 5250 Å (due to the doubled aperture diameter of 609.6 mm). This is well below the specified limit of 0.5 arcsec. The design is also well-corrected for color, as desired. There is no vignetting and the system should still have an overall transmission very close to that of the EXVM. The ray angles remain within the appropriate limits. The same 2X converter is used and does not reduce image quality or violate any constraints when inserted. The telescope should be of the same quality as the 30 cm version and the tolerances for the custom lenses should still be standard for precision optics. The spacing tolerance analysis results are summarized at the end of the appendix. Again, these tolerances should be divided by three to give system values. The most sensitive spacing remains the primary-to-secondary (around 1 μm). The secondary-to-collimating lens (6 μm) and the decollimating lens-to-negative lens (15 μm) air gaps are still sensitive along with the final imaging lens-to-field lens (36 μm) space. The only other tight tolerance is on the 1 mm air gap in the collimating lens (about 1 μm). The remaining air gap tolerances

60-CM SYSTEM WITH FABRY-PEROT FILTER

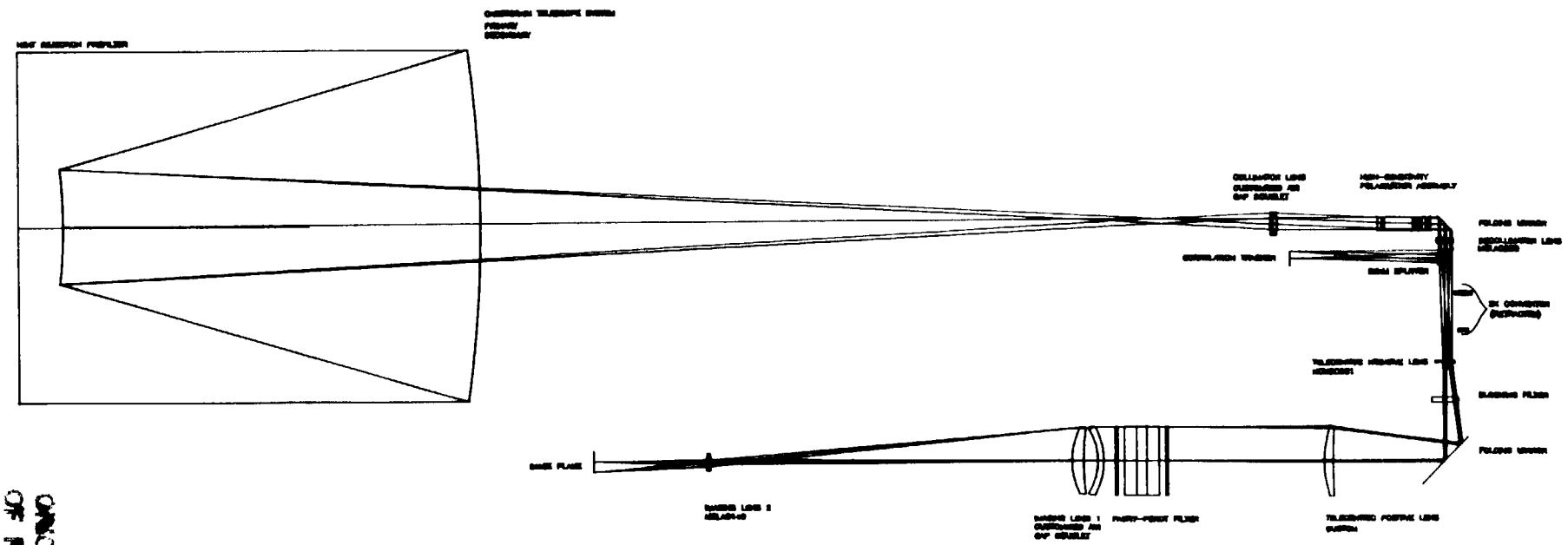

Fig. 5

60-CM SYSTEM WITH FABRY-PEROT FILTER & 2X CONVERTER
(EXBMF2)

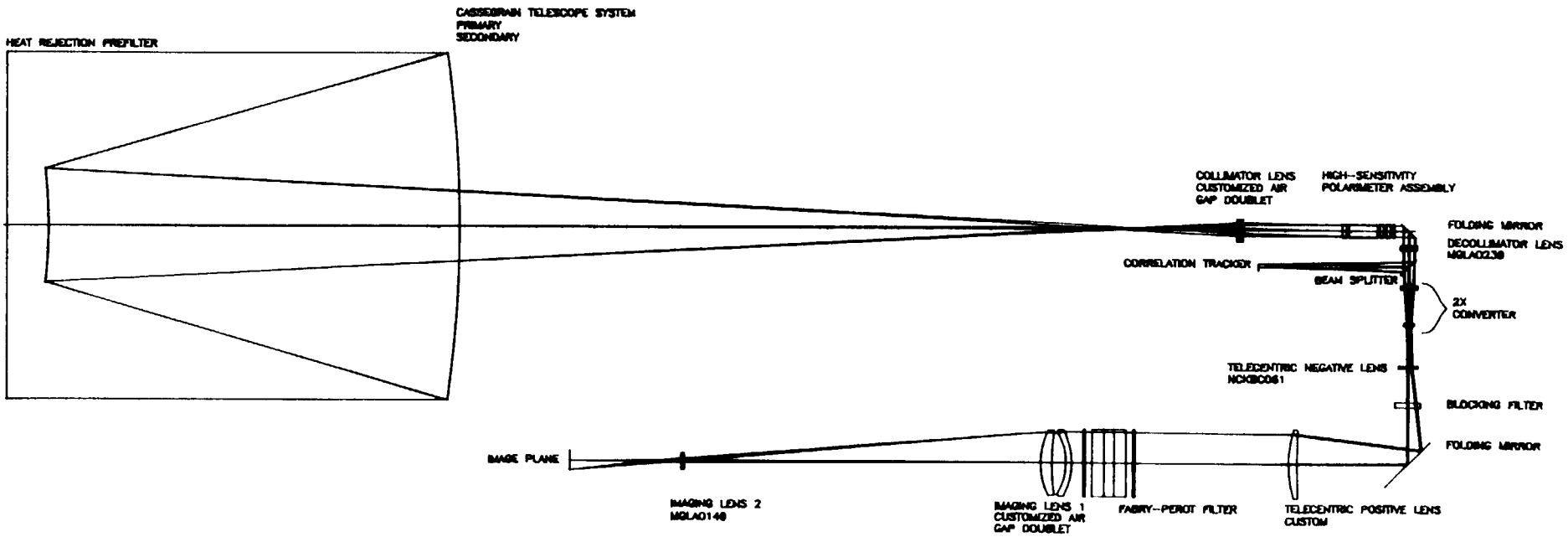

Fig. 6

are on the order of millimeters. The overall length is longer than that of the 30 cm designs at 4.5 m with the image splitter (even though not shown), and the entire system envelope is 2.45 m x 0.80 m. This is believed to be close to the minimum size for this configuration.

Another final design of the 60F system, 60F*, was developed (Appendix G). This system was developed as a less expensive alternative to the design above. It is a simpler design using off-the-shelf lenses and no higher-order aspherics on the telescope surfaces. It is, however, very long since the spacings were the only parameters available for control of physical limitations and image quality. The resultant image is not diffraction-limited but does meet the 0.5 arcsec resolution requirement (about the same performance as the 30 cm designs). The design is also fairly well corrected for color. There is no vignetting and the system transmission should be about the same as for the 2design above. The ray angles remain within the appropriate limits, and the same 2X converter is used. The overall length is quite long at 5.1 m with the image splitter, and the entire system envelope is 2.45 m x 1.10 m.

Lastly, the final design of the 60B system (Figures 7 & 8 below and Appendix H) was accomplished. The front end was kept the same as for the high-quality 60F design with the new design starting after the 2X converter. The lenses surrounding the Fabry-Perot consist of two specially designed air gap doublets to give the required compromise between telecentric and collimated space for the birefringent filter. The spacings were optimized along with these lenses. The resultant image quality is still diffraction-limited across the field at 5250 Å. The design is also still well-corrected for color. There is no vignetting and the system should have an overall transmission very close to that of the previous designs. The ray angles remain within the appropriate limits. The same 2X converter is used and does not reduce image quality or violate any constraints when inserted. The quality of the optical components should be the same as for the 60F design. The spacing tolerance analysis results are again summarized at the end of the appendix (listed tolerances should still be divided by three to give system values). The tolerances are very close to those for the 60F design with the primary-to-secondary (around 1 μm), the secondary-to-collimating lens (8 μm), and the decollimating lens-to-first telecentric lens (19 μm) air gaps still very sensitive. The air gap in the collimating lens is still sensitive also (about 1 μm). The remaining air gap tolerances are tighter than before at around 10 μm. The overall length is

60-CM SYSTEM WITH LYOT FITLER
(EXBVMB1)

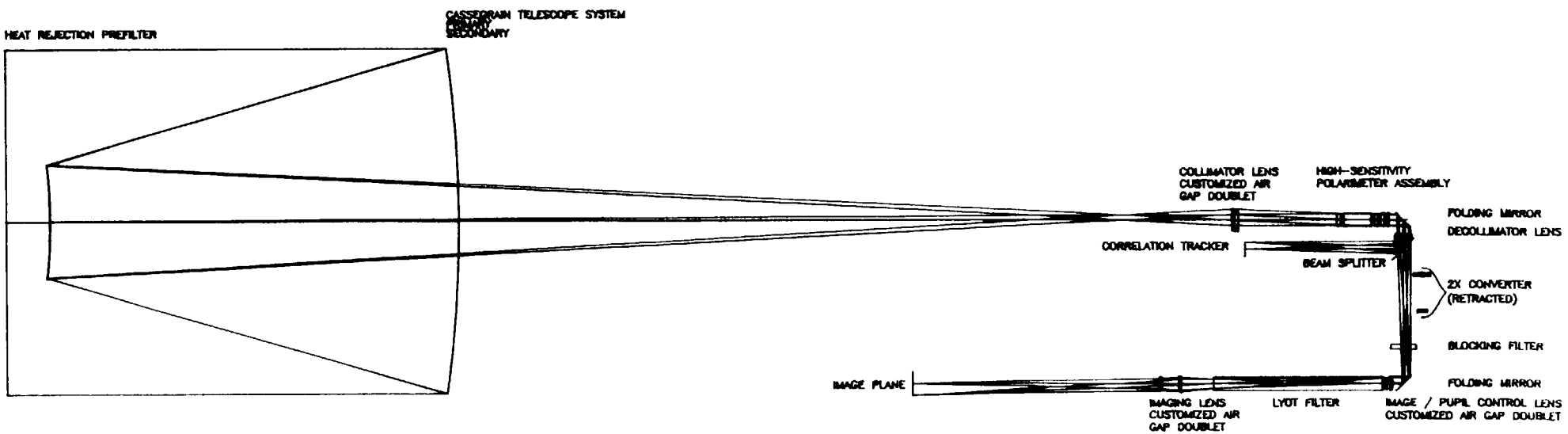

Fig. 7

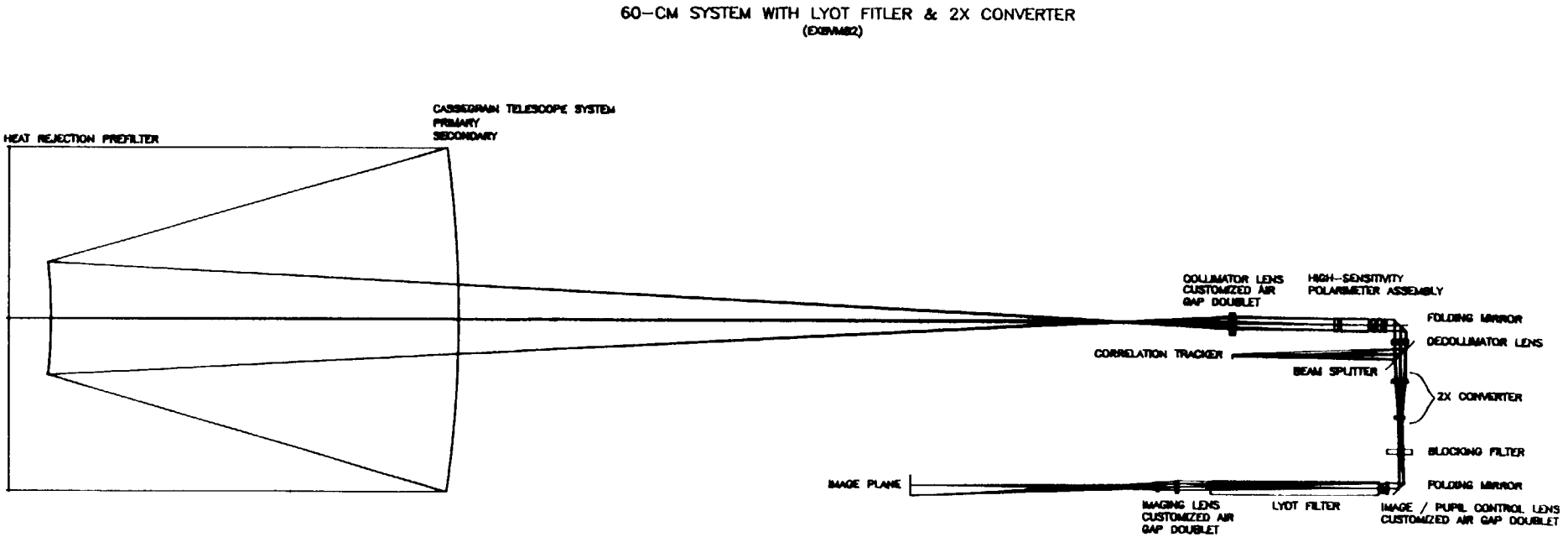
60-CM SYSTEM WITH LYOT FITLER & 2X CONVERTER
(EXPANDED)
HEAT REJECTION PREFILTER
CASSEGRAIN TELESCOPE SYSTEM
PRIMARY
SECONDARY
COLLIMATOR LENS
CUSTOMIZED AIR
GAP DOUBLET
HIGH-SENSITIVITY
POLARIMETER ASSEMBLY
FOLDING MIRROR
DECOLLIMATOR LENS
CORRELATION TRACKER
BEAM SPLITTER
2X CONVERTER
BLOCKING FILTER
IMAGE PLANE
FOLDING MIRROR
IMAGING LENS
CUSTOMIZED AIR
GAP DOUBLET
LYOT FILTER
IMAGE / PUPIL CONTROL LENS
CUSTOMIZED AIR GAP DOUBLET

Fig. 8

shorter than that of the 60F design at 3.8 m with the image splitter, with an entire system envelope of 2.45 m x 0.63 m.

The correlation tracker image (Appendix I) is exactly the same for both of the custom 60 cm designs. It is diffraction-limited as desired with about half the size of the final image. As stated before, the correlation tracker beamsplitter can go before or after the 2X converter as desired. The correlation tracker image for the back-up 60F* design is only 70% of the desired size and is not quite diffraction-limited.

The idea of an articulated secondary telescope mirror to accomplish the fine system pointing was also explored. The 30F and 60F designs were analyzed. Each system was tilted by set amounts, starting at 25 arcsec, and the secondary then tilted to bring the image back to the center of the image plane. The MTF was then examined for image quality across the new field of view. The results are given in Appendix J with the system tilts and secondary mirror tilts listed (in degrees) on each MTF plot. For the 30 cm system, up to ±200 arcsec of pointing (or ±375 arcsec of secondary tilt) can be accomplished without serious degradation of the image quality. At ±500 arcsec the image quality has deteriorated significantly. For the 60 cm system, only about ±25 arcsec of pointing (or ±40 arcsec of secondary tilt) can be tolerated before the image quality is lost. This is quite evident in the plots at ±50 & ±100 arcsec. The 60 cm telescope is more sensitive since more of its power is placed on the primary mirror. In other words, the higher primary magnification amplifies the effects of system tilt at the secondary. The 60 cm telescope may be able to be changed slightly to enhance the pointing capability if required. However, due to the fact that it was designed to meet the strict aperture requirements of the polarimeter and filters, changes should be made very carefully and only after a careful analysis of the trade-offs involved. The above results should also be applicable to the birefringent designs since they use the same telescopes. Based on these findings, done without any consideration of polarization effects, the articulated secondary approach seems to be a viable alternative, within the limits described, for use on the BVM.

In summary, all of the final designs above meet the NASA performance specifications while not violating the physical constraints. A full set of 1/4-scale drawings, with complete component specifications, was previously delivered to ES52. Reprints of these drawings can be obtained upon request.

The drawings have also been presented on floppy disk in both Autocad Release 11 format and in a form that can be printed from DOS to an HP Laserjet printer with at least 2 Mbytes of RAM (using the COPY filename PRN /B command). Lastly, the cost of the 30 cm systems should be very close to that of the EXVM while the 60 cm systems will differ by the added cost of the telescope and the few custom lenses used.

5. Polarization Effects Monitoring of BVM

Throughout the first-order and final design stages of this effort, the polarization analysis team headed by Russell Chipman of UAH was closely involved. Each design was monitored and analyzed for potential polarization problems and the final designs were deemed acceptable. The collimating lens before the polarimeter was not thought to be optimum, but can be handled with a stress-free glass. Also, the larger 60 cm telescope may require slightly more complicated coatings than the 30 cm system. However, this will be a very small factor in the overall cost of one of the larger systems. Further details can be obtained from the polarization analysis team.

6. Conclusion

All major objectives were accomplished for this effort yielding four complete final optical designs (plus one backup) for a balloon-borne solar vector magnetograph. Once the results of EXVM testing are available, a final optical design can be selected and will be immediately available for initiation of the final engineering design effort for the instrument.

APPENDIX A

Original EXVM Design

spe

LENS SPECIFICATION
ID EXVM

1147

OBJ. DIST.	INFINITE	FOCAL LENGTH	-14786.8405
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	103.0311
MARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	105.1380
CHIEF RAY HEIGHT	-.9265	OVERALL LENGTH	2486.5002
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0817	EXIT PUPIL POS.	-34.0564
F/NUMBER	-48.5133	GAUSSIAN IM. HT.	-20.7583

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION .145630E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOTT
2	INFINITE	650.00000	AIR		
3	-2394.73740	-877.23980	-AIR		
CONIC B	-.239474E+14				
AXES A	.239474E+09	CC	-.100000E+01		
4	-858.24060	1069.00000	AIR		
CONIC B	.470171E+03				
AXES A	-.635232E+03	CC	-.282538E+01		
5	INFINITE	7.00000	BK7	1.51987T	678.41 SCHOTT
6	INFINITE	5.00000	AIR		
7	INFINITE	50.00000	BK7	1.51987T	678.41 SCHOTT
8	INFINITE	5.00000	AIR		
9	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
10	INFINITE	5.00000	AIR		
11	INFINITE	7.00000	BK7	1.51987T	678.41 SCHOTT
12	INFINITE	5.00000	AIR		
13	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
14	INFINITE	315.00000	AIR		
15	718.39000	4.00000	SF8	1.69736T	358.07 SCHOTT
16	92.73000	6.60000	SSK4	1.62192T	598.46 SCHOTT
17	-128.08000	105.00000	AIR		
18	INFINITE	300.00000	BK7	1.51987T	678.41 SCHOTT
19	INFINITE	17.00000	AIR		
20A	INFINITE	.00000	-AIR		
21A	INFINITE	-16.50000	-AIR		
22	-210.75000	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
23	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
24	515.63000	-203.87537	-AIR		
25	141.25000	-4.80000	SF5	-1.68067T	368.78 SCHOTT
26	47.31500	-3.00000	BK7	-1.51987T	678.41 SCHOTT
27	-61.74800	-15.00000	-AIR		
28	INFINITE	-.01000	BK7	-1.51987T	678.41 SCHOTT
29	INFINITE	-48.00000	-AIR		
30	INFINITE	-4.00000	BK7	-1.51987T	678.41 SCHOTT
31	INFINITE	-48.00000	-AIR		
32	INFINITE	-.01000	BK7	-1.51987T	678.41 SCHOTT

33	INFINITE	-65.00000	-AIR			
34A	INFINITE	.00000	AIR			
35A	INFINITE	47.01663	AIR			
36	188.36000	12.50000	BK7	1.51987T	678.41	SCHOTT
37	-139.24000	6.00000	SF5	1.68067T	368.78	SCHOTT
38	-415.67000	220.23331	AIR			
39	INFINITE	4.00000	BK7	1.51987T	678.41	SCHOTT
40	INFINITE	12.00000	AIR			
41	INFINITE	21.00000	BK7	1.51987T	678.41	SCHOTT
42	INFINITE	.00028	AIR			
43	INFINITE	18.00000	BK7	1.51987T	678.41	SCHOTT
44	INFINITE	.00000	AIR			
45	INFINITE	21.00000	BK7	1.51987T	678.41	SCHOTT
46	INFINITE	12.00000	AIR			
47	INFINITE	4.00000	BK7	1.51987T	678.41	SCHOTT
48	INFINITE	80.00000	AIR			
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51	-302.87000	439.00000	AIR			
52	121.71195	3.80000	BK7	1.51987T	678.41	SCHOTT
53	-89.71796	2.50000	SF5	1.68067T	368.78	SCHOTT
54	-268.15906	274.64653	AIR			
55	192.49000	6.65000	SK11	1.56737T	650.90	SCHOTT
56	-136.61000	8.00000	SF5	1.68067T	368.78	SCHOTT
57	-552.26000	.00000	AIR			
58	552.26000	8.00000	SF5	1.68067T	368.78	SCHOTT
59	136.61000	6.65000	SK11	1.56737T	650.90	SCHOTT
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62A	INFINITE	-88.68000	-AIR			
63A	INFINITE	.00000	AIR			
64A	INFINITE	80.00000	AIR			
65	64.04000	4.80000	SK11	1.56737T	650.90	SCHOTT
66	-44.88000	2.00000	SF5	1.68067T	368.78	SCHOTT
67	-182.72000	40.00000	AIR			
68A	INFINITE	.00000	-AIR			
69A	INFINITE	-59.39900	-AIR			
70A	INFINITE	.00000	AIR			
71A	INFINITE	103.03107	AIR			
72	INFINITE	2.10696	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

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.000000E+00	.000000E+00	.000000E+00	
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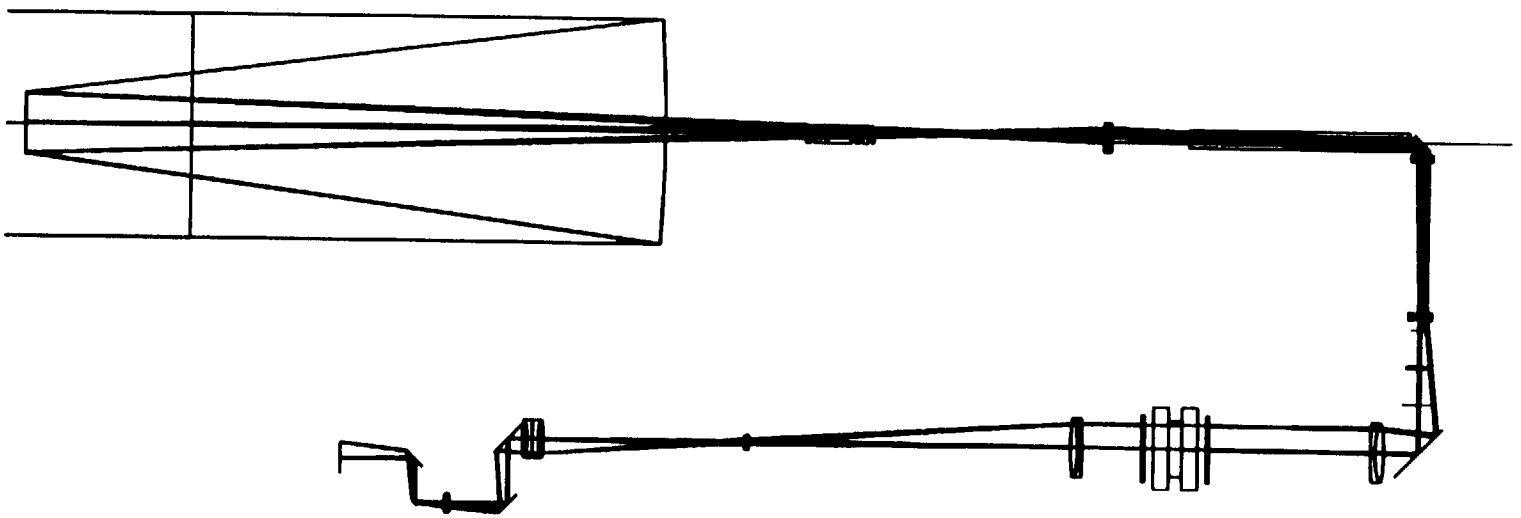

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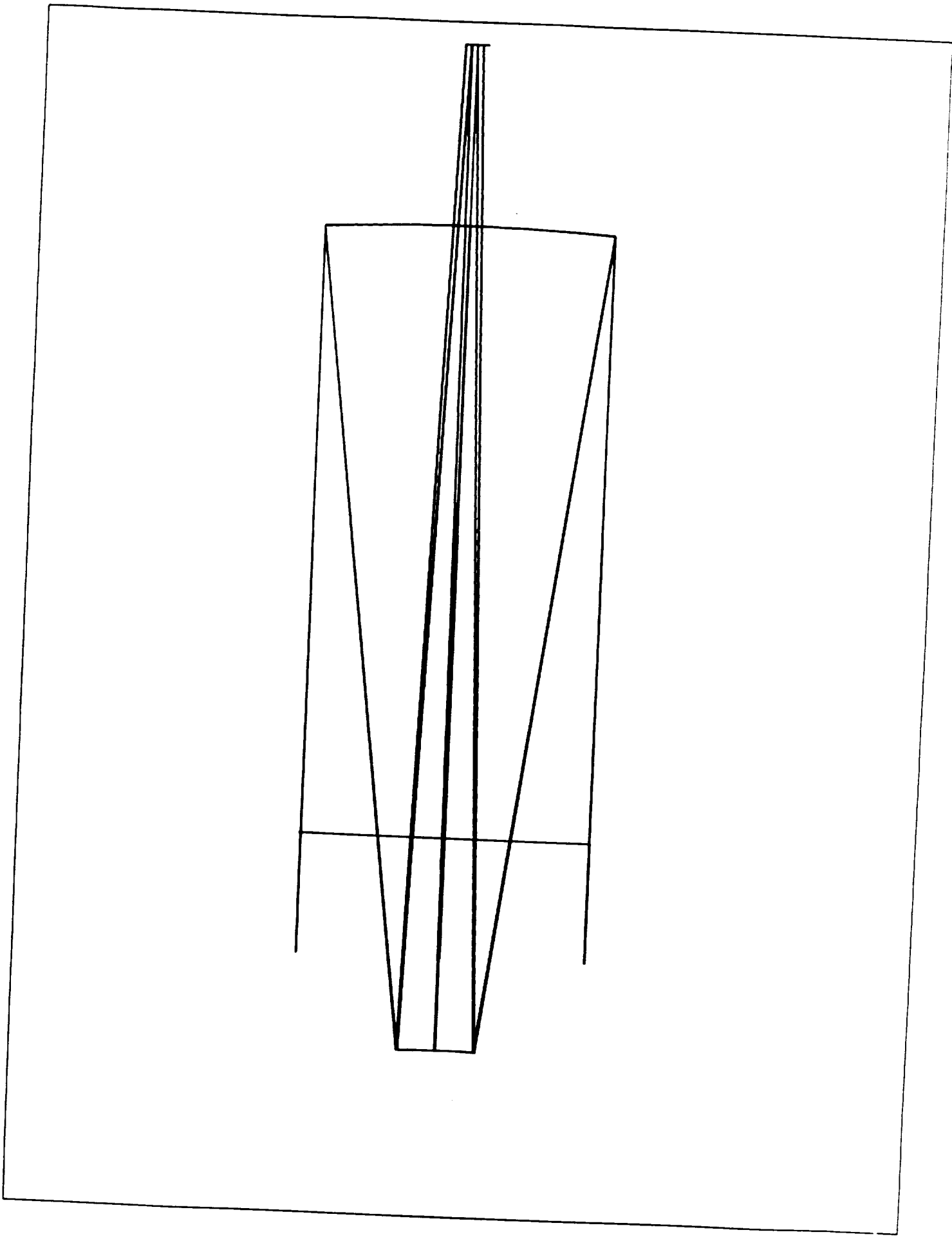

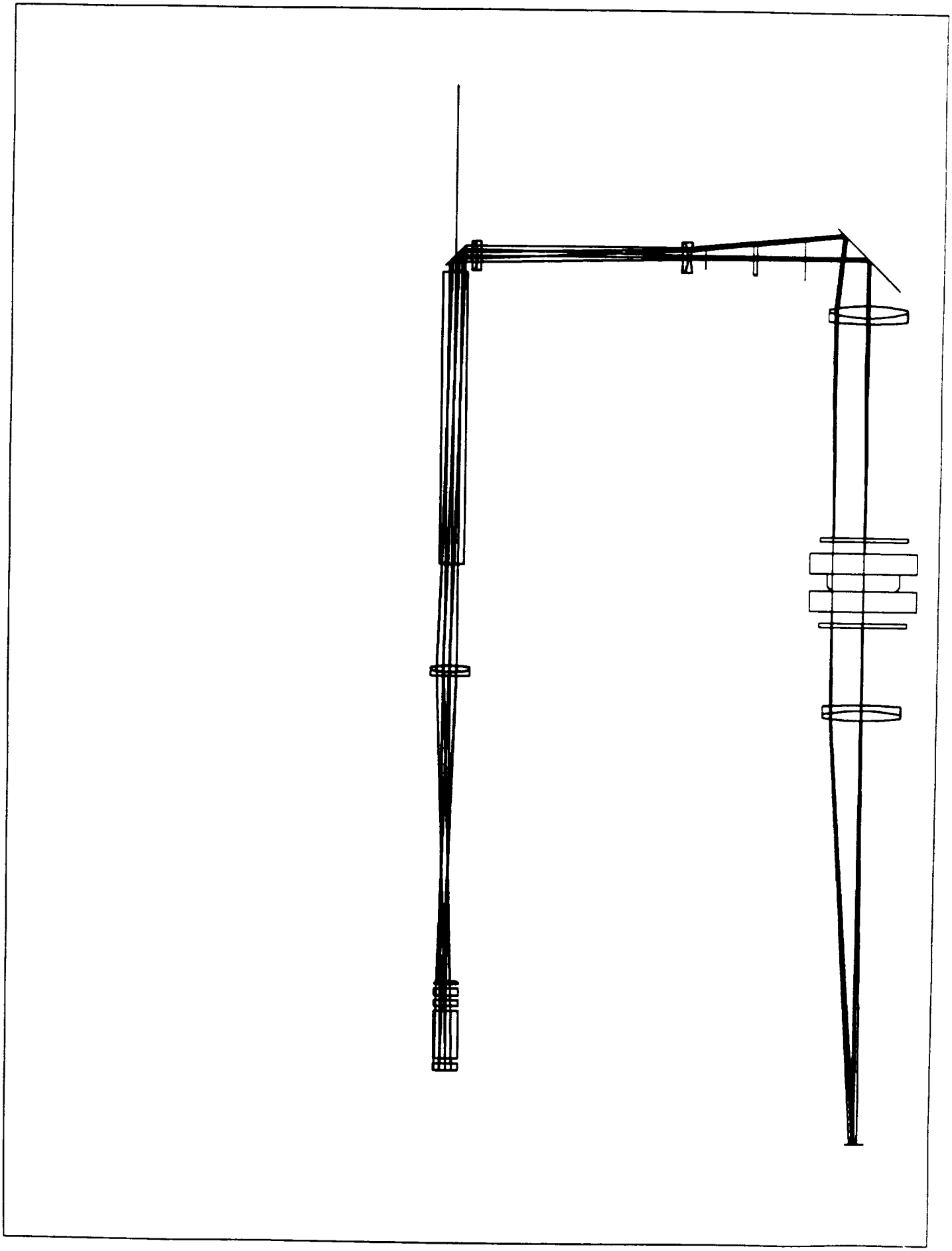

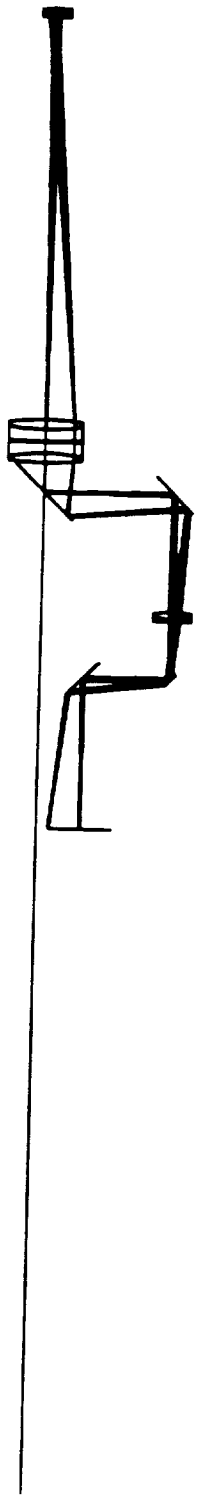

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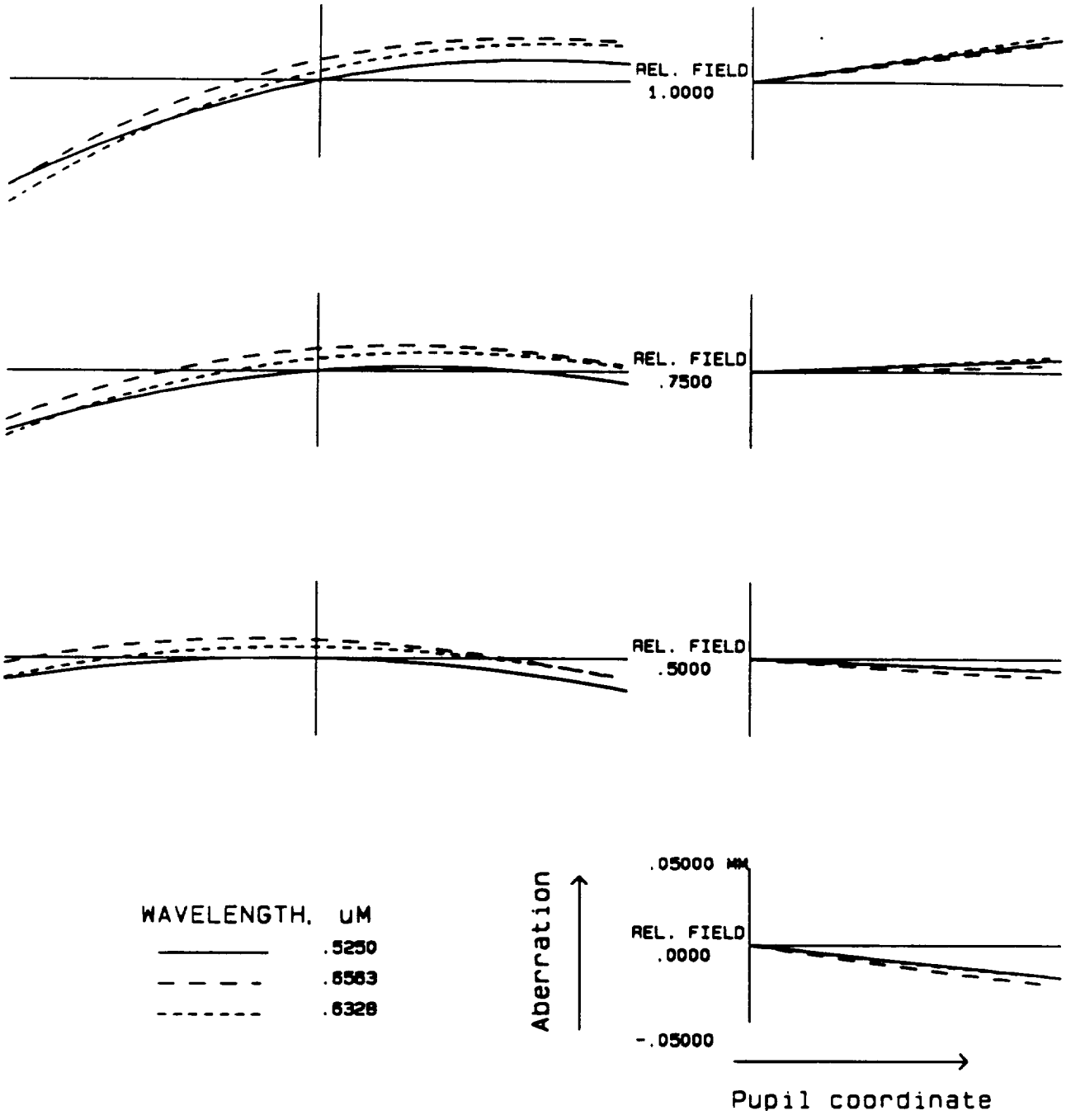

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1147

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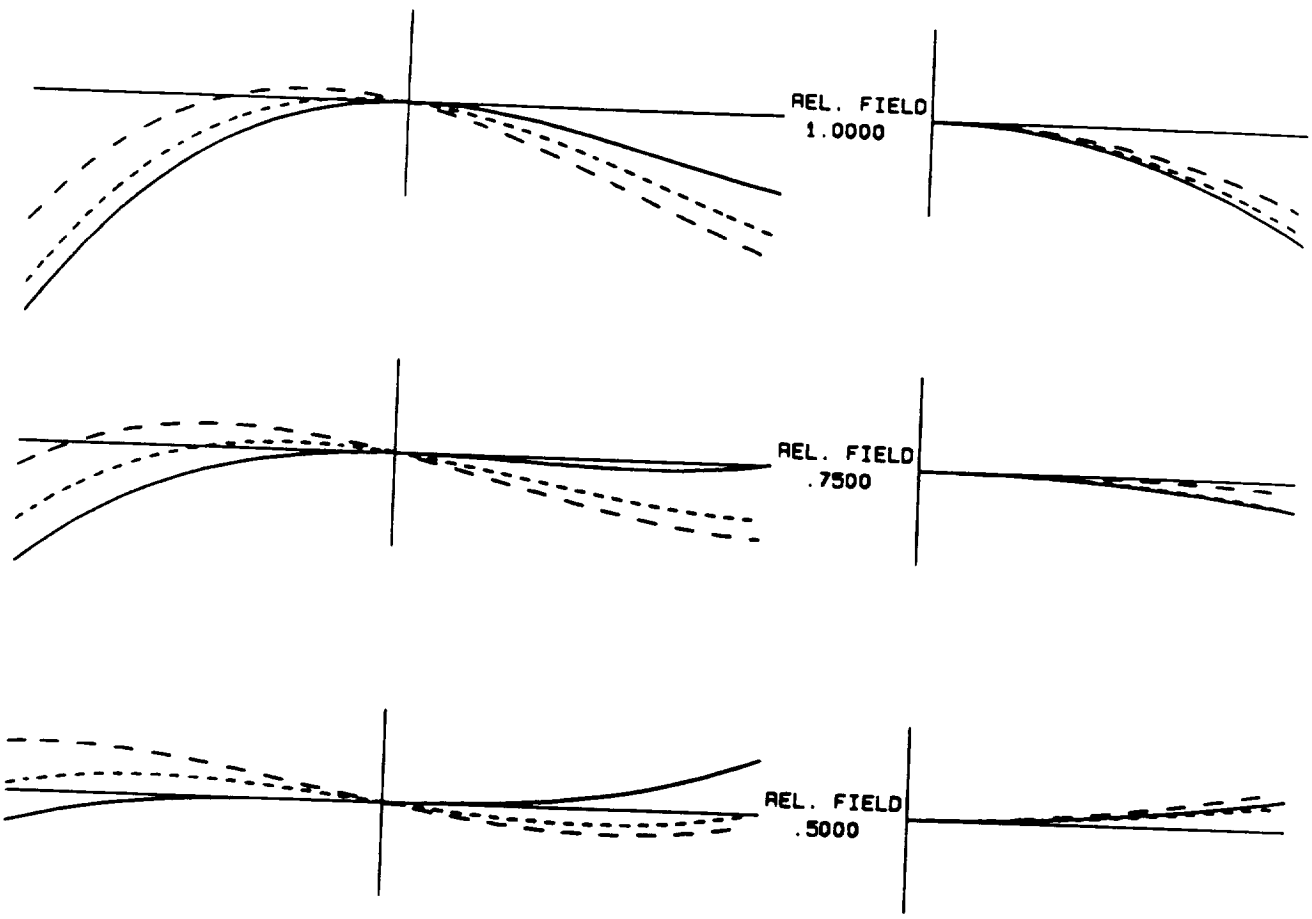

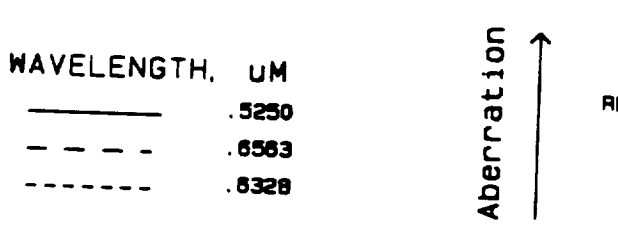

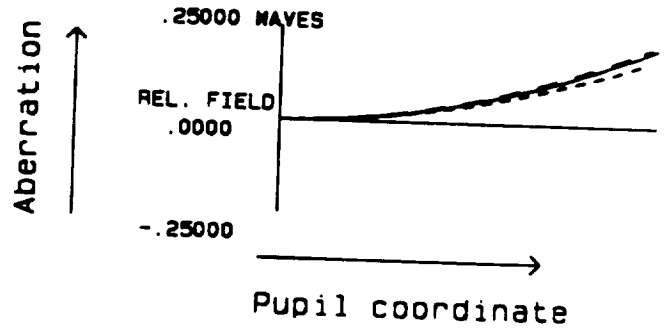

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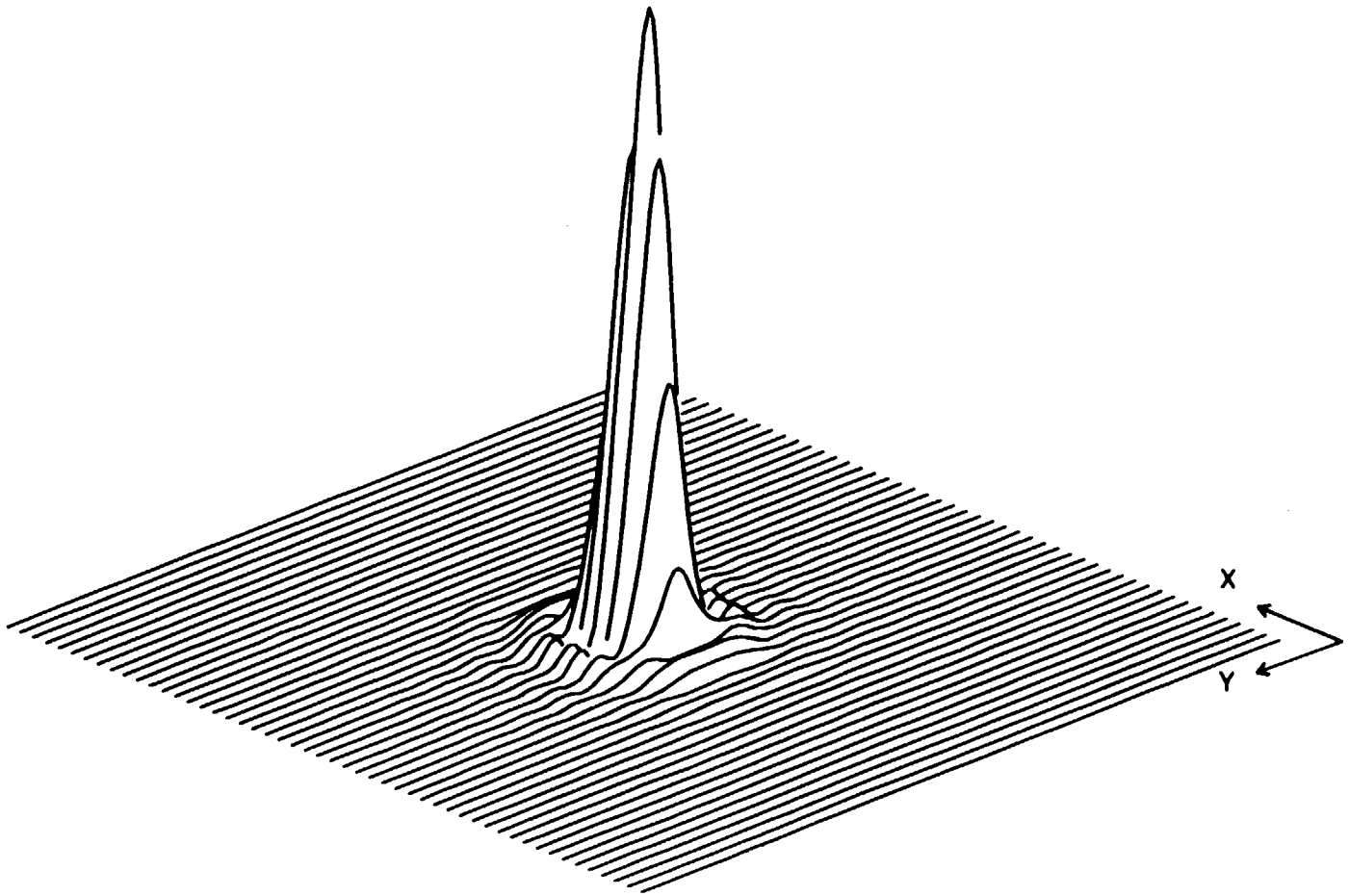

AIRY DISK RADIUS .031066 MM ID EXVM

PSPRD 2 0. 300 0 0. WAVELENGTH .52502

FRACTIONAL FIELD .0000 .0000

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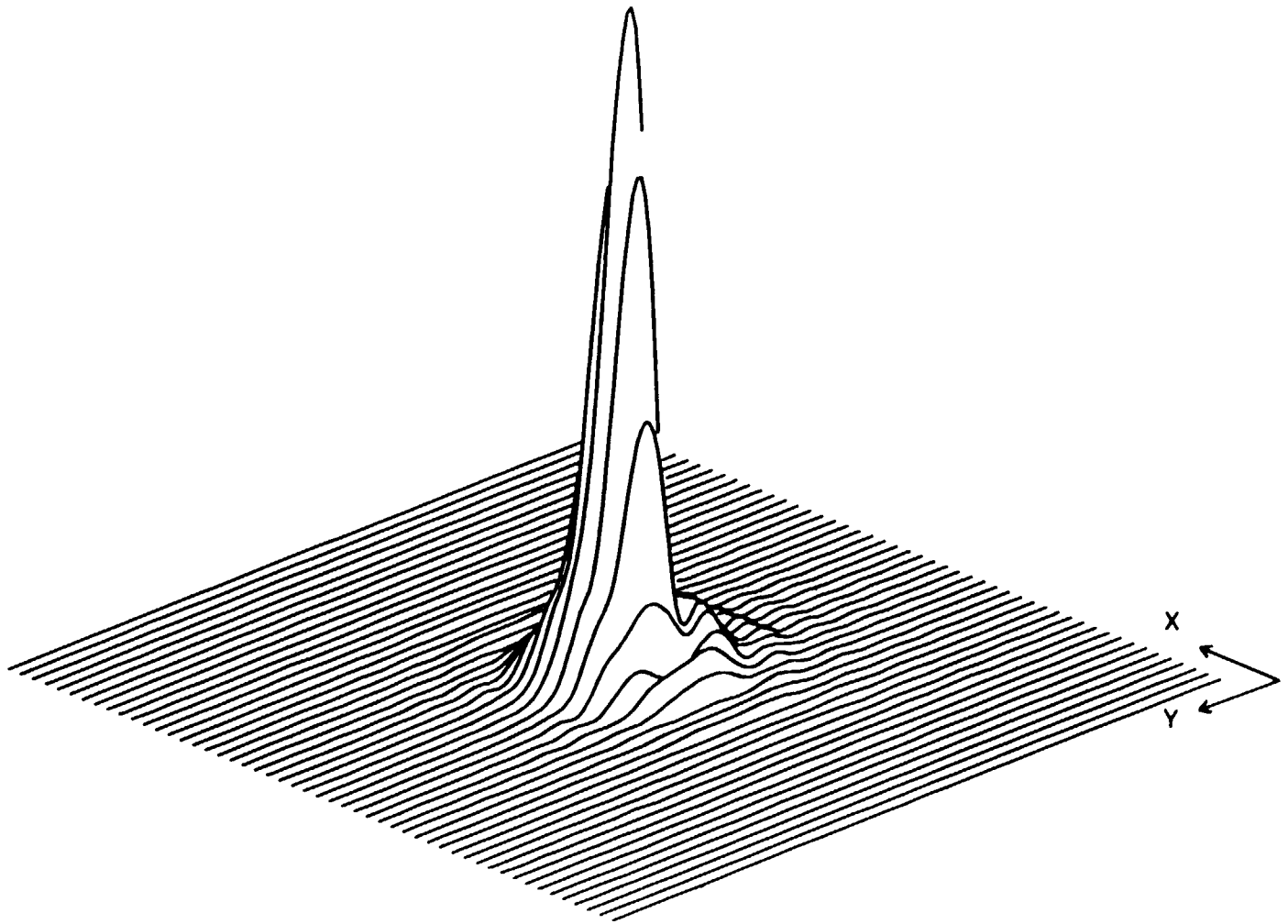
1147

7-Apr-92 11:40:51

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .030411 MM ID EXVM

PSPRD 2 1. 300 0 0. WAVELENGTH .52502

FRACTIONAL FIELD 1.0000 .0000

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

1147

7-Apr-92 11:38:57

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .0000 FIELD 1.0000 FIELD
SAG.

WAVELENGTH	WEIGHT
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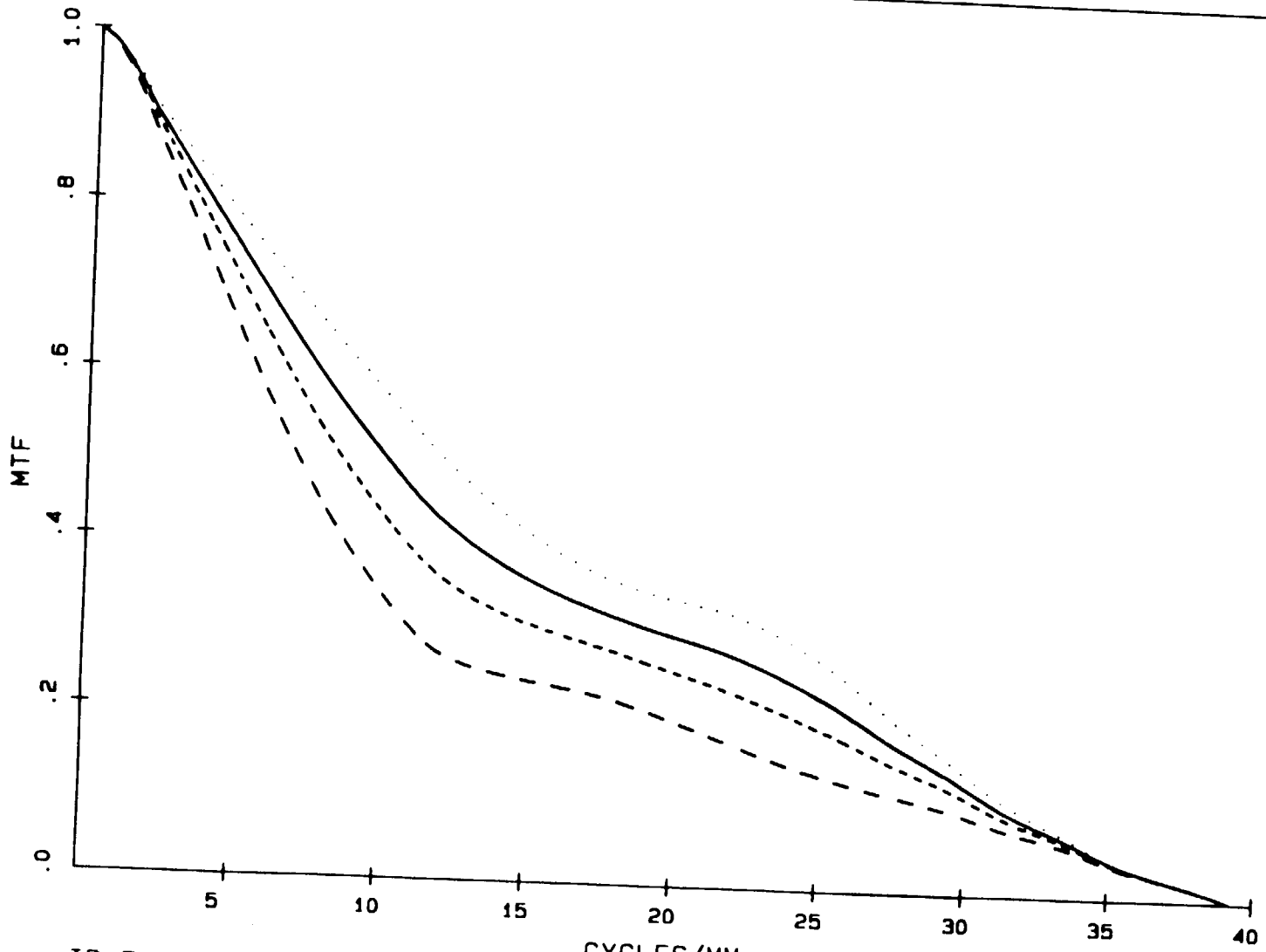

ID EXVM
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

1147

DEFOCUS -2.106959

PE

ENS SPECIFICATION
D EXVMC

1147

BJ. DIST.	INFINITE	FOCAL LENGTH	-7144.4137
BJ. HEIGHT	INFINITE	BACK FOCAL DIST.	180.9449
ARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	181.3293
HIEF RAY HEIGHT	-.9265	OVERALL LENGTH	1536.4612
ARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
HIEF RAY ANGLE	.0817	EXIT PUPIL POS.	-303.5966
/NUMBER	-23.4397	GAUSSIAN IM. HT.	-10.1757

AVELENGTHS .65627 .52502 .63280
NITS MM
TOP IS ON SURF. NO. 3
ENS IS FOCAL, MAGNIFICATION .713875E-07
LOBAL OPTION IS ON
OLARIZATION AND COATINGS ARE IGNORED.

URF. NO.	RADIUS	THICKNESS	MEDIUM			
1	INFINITE	.00100	BK7	1.51987T	678.41	SCHOTT
2	INFINITE	650.00000	AIR			
3	-2394.73740	-877.23980	-AIR			
CONIC B	-.239474E+14					
AXES A	.239474E+09	CC	-.100000E+01			
4	-858.24060	1069.00000	AIR			
CONIC B	.470171E+03					
AXES A	-.635232E+03	CC	-.282538E+01			
5	INFINITE	7.00000	BK7	1.51987T	678.41	SCHOTT
6	INFINITE	5.00000	AIR			
7	INFINITE	50.00000	BK7	1.51987T	678.41	SCHOTT
8	INFINITE	5.00000	AIR			
9	INFINITE	6.00000	BK7	1.51987T	678.41	SCHOTT
10	INFINITE	5.00000	AIR			
11	INFINITE	7.00000	BK7	1.51987T	678.41	SCHOTT
12	INFINITE	5.00000	AIR			
13	INFINITE	3.00000	BK7	1.51987T	678.41	SCHOTT
14	INFINITE	315.00000	AIR			
15	718.39000	4.00000	SF8	1.69736T	358.07	SCHOTT
16	92.73000	6.60000	SSK4	1.62192T	598.46	SCHOTT
17	-128.08000	105.00000	AIR			
18	INFINITE	300.00000	BK7	1.51987T	678.41	SCHOTT
19	INFINITE	17.00000	AIR			
20A	INFINITE	.00000	-AIR			
21A	INFINITE	-16.50000	-AIR			
22	-210.75000	-5.00000	BAK4	-1.57269T	607.06	SCHOTT
23	81.29000	-4.40000	F3	-1.61924T	418.06	SCHOTT
24	515.63000	-120.00000	-AIR			
25A	INFINITE	.00000	AIR			
26A	INFINITE	180.94488	AIR			
27	INFINITE	.38441	AIR			

OTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

INFORMATION CONTINUED

```
:ILTS AND DECENTERS     ALPHA,BETA,GAMMA,AXIS
-DECN,YDECN,ZDECN

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    .000000E+00       .000000E+00     .000000E+00
  21      TDC    70  SURFACES
    .450000E+02       .000000E+00     .000000E+00     .000000E+00
    .000000E+00       .000000E+00     .000000E+00
  25      TDC    10  SURFACES
    .450000E+02       .000000E+00     .000000E+00     .000000E+00
    .000000E+00       .000000E+00     .000000E+00
  26      TDC    10  SURFACES
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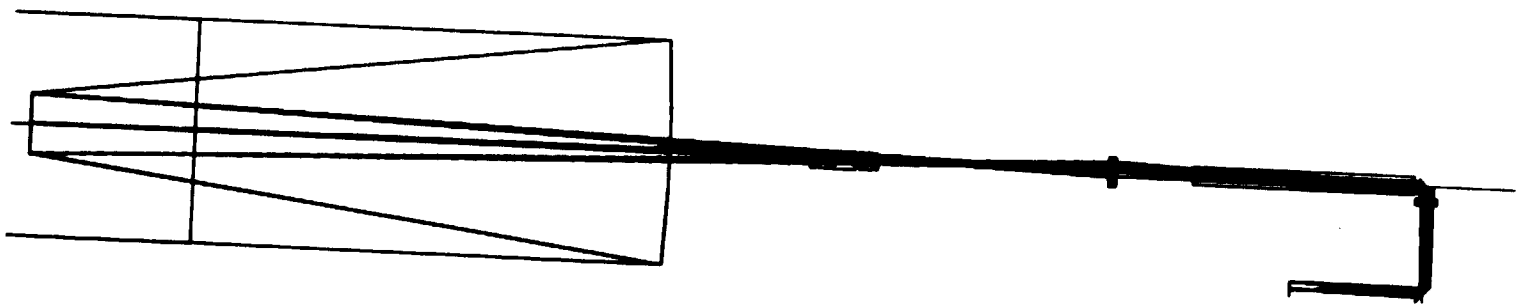
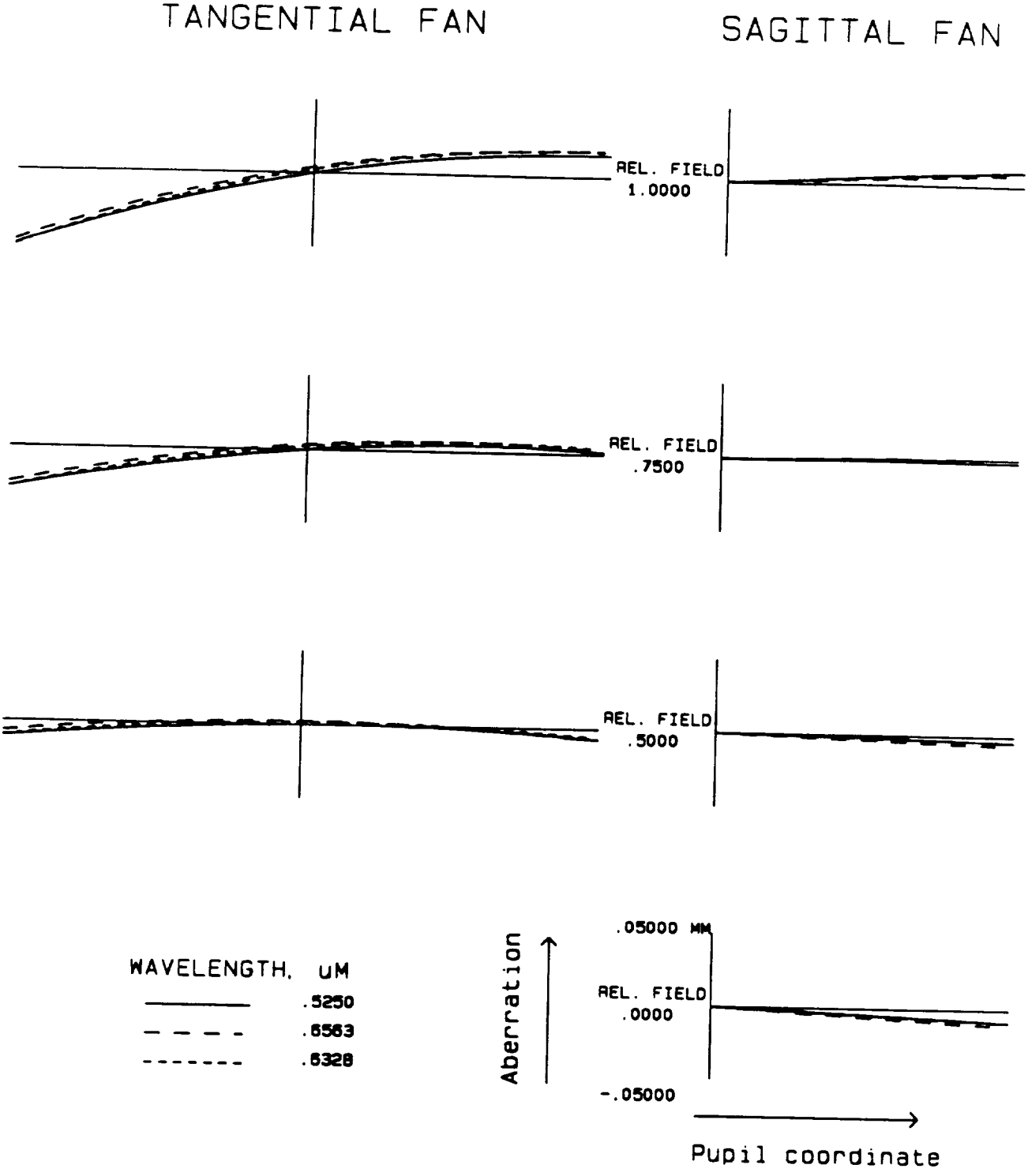


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EXVMC

31-Mar-92 09 06 09

TRANSVERSE ABERRATION



ID EXVMC

1146

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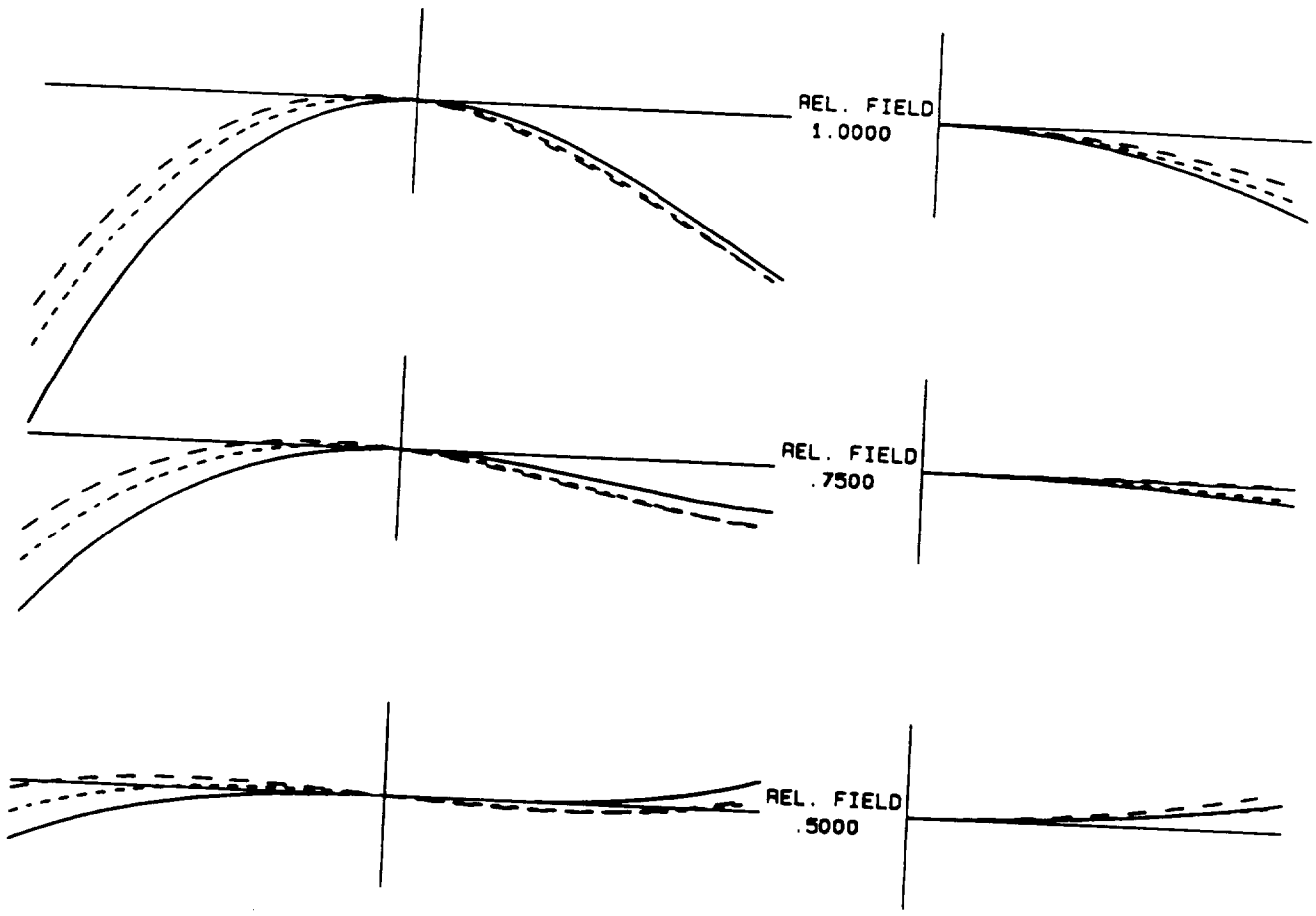
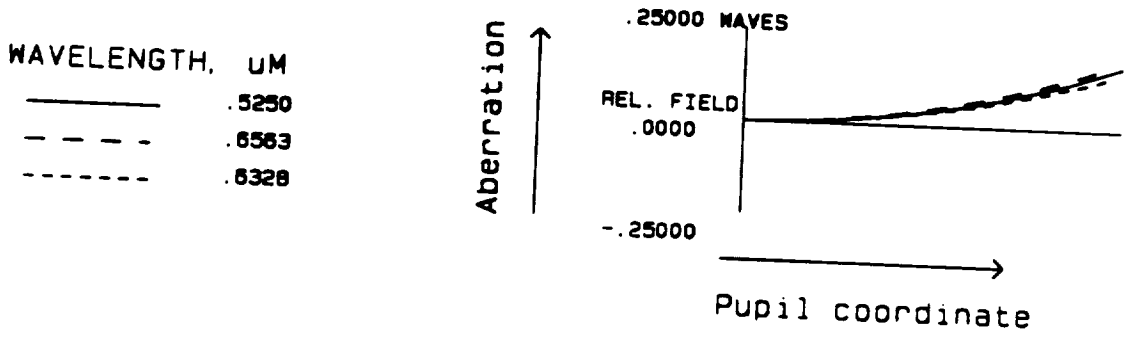
OPTICAL PATH DIFFERENCE





ID EXVMC

1146

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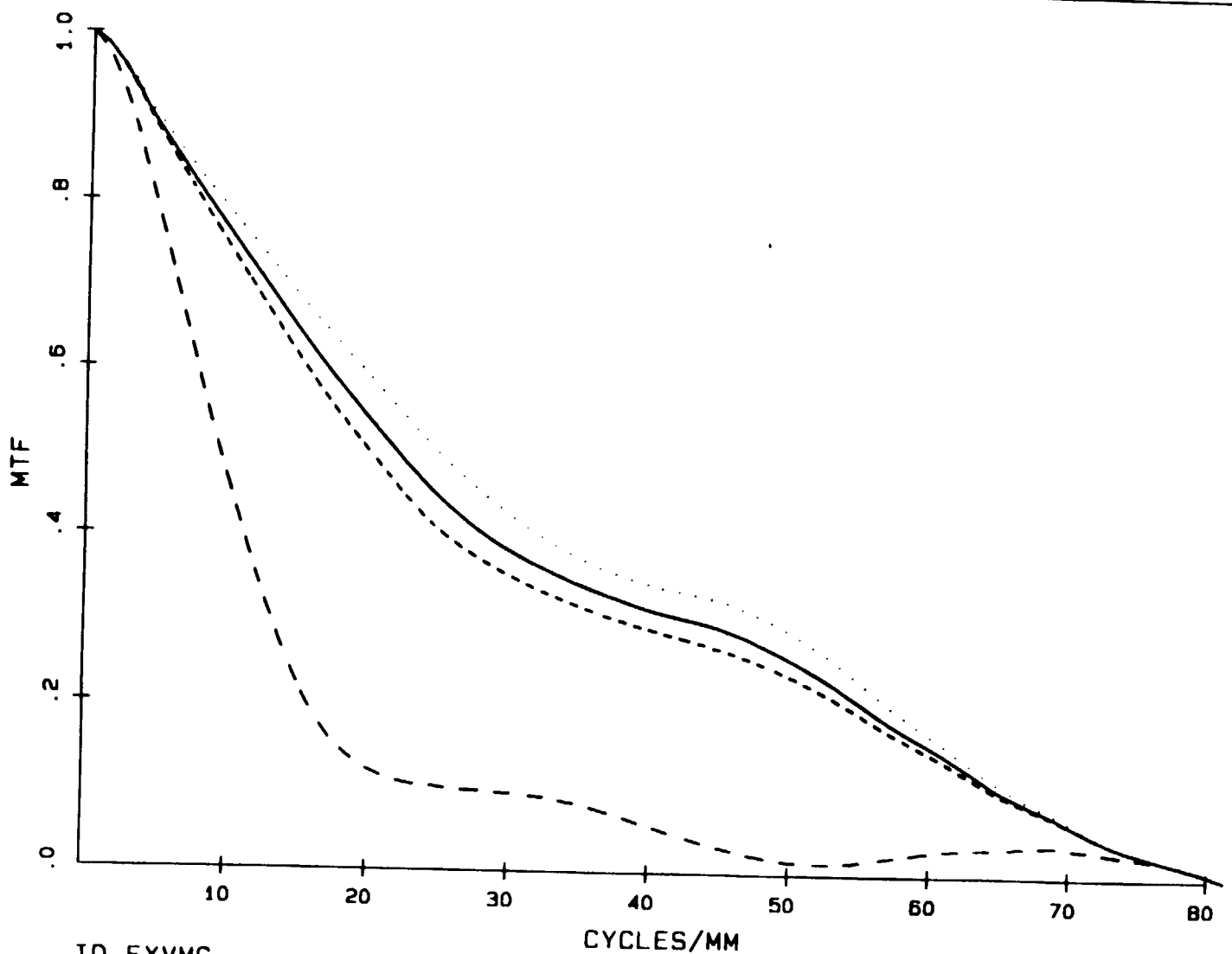
MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .....
SAG. .....

.0000 FIELD ——— ——— 1.0000 FIELD — — — - - - - - -

WAVELENGTH	WEIGHT
.52502	1.000



ID EXVMC
1147
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DEFOCUS -.384412

22-Oct-92 15:13:43

APPENDIX B

Optimized EXVM Design

SYNOPSYS AI> SPE
LENS SPECIFICATION
ID EXVMRGLR REOPTIMIZED ORIGINAL W/ R 1147

OBJ. DIST.	INFINITE	FOCAL LENGTH	-14893.8427
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	103.0311
MARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	105.3886
CHIEF RAY HEIGHT	-.9265	OVERALL LENGTH	2416.4738
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0817	EXIT PUPIL POS.	-31.5847
F/NUMBER	-48.8643	GAUSSIAN IM. HT.	-20.8645

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION .146375E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOT
2	INFINITE	650.00000	AIR		
3	-2394.73740	-877.23980	-AIR		
CONIC B	-.239474E+14				
AXES A	.239474E+09	CC	-.100000E+01		
4	-858.24060	1069.00000	AIR		
CONIC B	.470171E+03				
AXES A	-.635232E+03	CC	-.282538E+01		
5	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSU
6	INFINITE	5.00000	AIR		
7	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSU
8	INFINITE	5.00000	AIR		
9	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOT
10	INFINITE	5.00000	AIR		
11	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSU
12	INFINITE	5.00000	AIR		
13	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOT
14	INFINITE	320.40276	AIR		
15	718.39000	4.00000	SF8	1.69736T	358.07 SCHOT
16	92.73000	6.60000	SSK4	1.62192T	598.46 SCHOT
17	-128.08000	105.00000	AIR		
18	INFINITE	300.00000	CALCITE	1.66356T	529.15 UNUSU
19	INFINITE	17.00000	AIR		
20A	INFINITE	.00000	-AIR		
21A	INFINITE	-16.50000	-AIR		
22	-210.75000	-5.00000	BAK4	-1.57269T	607.06 SCHOT
23	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOT
24	515.63000	-203.87537	-AIR		
25	141.25000	-4.80000	SF5	-1.68067T	368.78 SCHOT
26	47.31500	-3.00000	BK7	-1.51987T	678.41 SCHOT
27	-61.74800	-15.00000	-AIR		
28	INFINITE	-.01000	BK7	-1.51987T	678.41 SCHOT
29	INFINITE	-48.00000	-AIR		
30	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSU
31	INFINITE	-48.00000	-AIR		
32	INFINITE	-.01000	BK7	-1.51987T	678.41 SCHOT
33	INFINITE	-65.00000	-AIR		
34A	INFINITE	.00000	AIR		
35A	INFINITE	37.77102	AIR		
36	188.36000	12.50000	BK7	1.51987T	678.41 SCHOT
37	-139.24000	6.00000	SF5	1.68067T	368.78 SCHOT
38	-415.67000	156.99333	AIR		

39	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUS
40	INFINITE	12.00000	AIR			
41	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUS
42	INFINITE	.00028	AIR			
43	INFINITE	18.00000	FUSILICA	1.46104T	712.58	UNUS
44	INFINITE	.00000	AIR			
45	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUS
46	INFINITE	12.00000	AIR			
47	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUS
48	INFINITE	80.00000	AIR			
49	673.17000	6.00000	SF5	1.68067T	368.78	SCHOT
50	222.27000	10.00000	BK7	1.51987T	678.41	SCHOT
51	-302.87000	439.00000	AIR			
52	121.71195	3.80000	BK7	1.51987T	678.41	SCHOT
53	-89.71796	2.50000	SF5	1.68067T	368.78	SCHOT
54	-268.15906	277.20299	AIR			
55	192.49000	6.65000	SK11	1.56737T	650.90	SCHOT
56	-136.61000	8.00000	SF5	1.68067T	368.78	SCHOT
57	-552.26000	.00000	AIR			
58	552.26000	8.00000	SF5	1.68067T	368.78	SCHOT
59	136.61000	6.65000	SK11	1.56737T	650.90	SCHOT
60	-192.49000	20.01663	AIR			
61A	INFINITE	.00000	-AIR			
62A	INFINITE	-88.68000	-AIR			
63A	INFINITE	.00000	AIR			
64A	INFINITE	80.00000	AIR			
65	64.04000	4.80000	SK11	1.56737T	650.90	SCHOT
66	-44.88000	2.00000	SF5	1.68067T	368.78	SCHOT
67	-182.72000	40.00000	AIR			
68A	INFINITE	.00000	-AIR			
69A	INFINITE	-59.39900	-AIR			
70A	INFINITE	.00000	AIR			
71A	INFINITE	103.03107	AIR			
72	INFINITE	2.35750	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

TILTS AND DECENTERS
X-DECN,YDECN,ZDECN

ALPHA,BETA,GAMMA,AXIS

20 TDC 70 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
21 TDC 70 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
34 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
35 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
61 TDC 30 SURFACES				
-.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
62 TDC 30 SURFACES				
-.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
63 TDC 30 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
64 TDC 30 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		

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     .000000E+00        .000000E+00     .000000E+00
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     .450000E+02        .000000E+00     .000000E+00     .000000E+00
     .000000E+00        .000000E+00     .000000E+00
    70      TDC    20  SURFACES
    -.450000E+02        .000000E+00     .000000E+00     .000000E+00
     .000000E+00        .000000E+00     .000000E+00
    71      TDC    20  SURFACES
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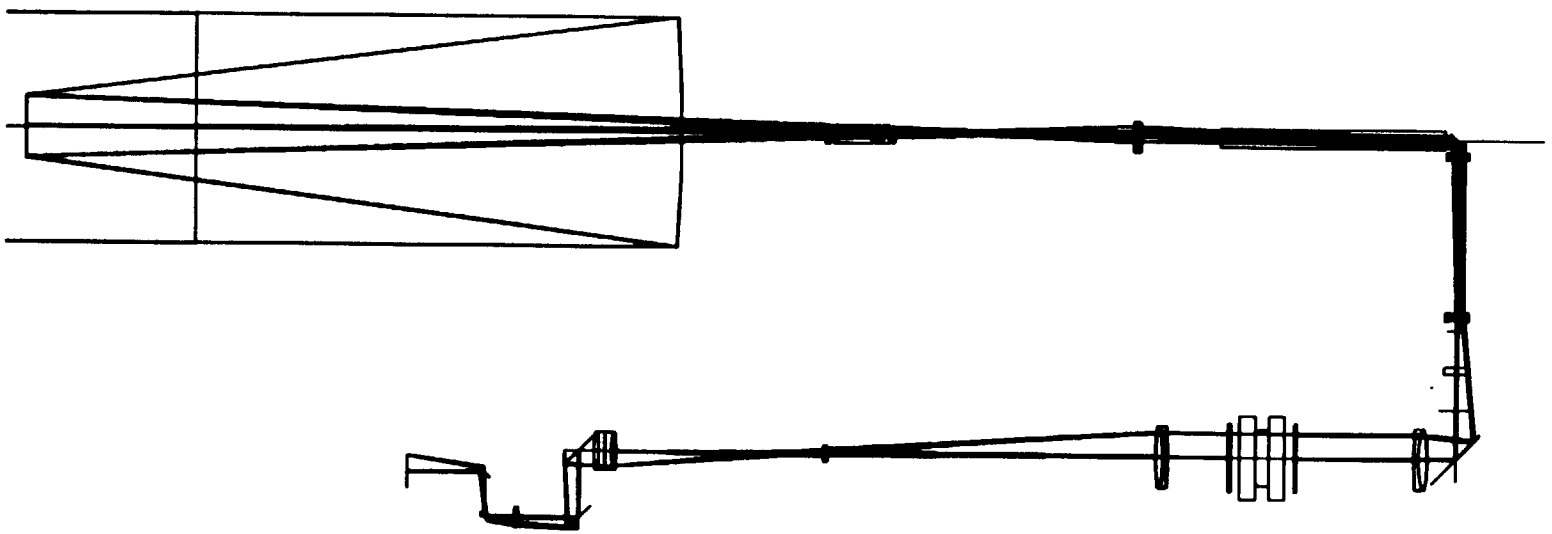
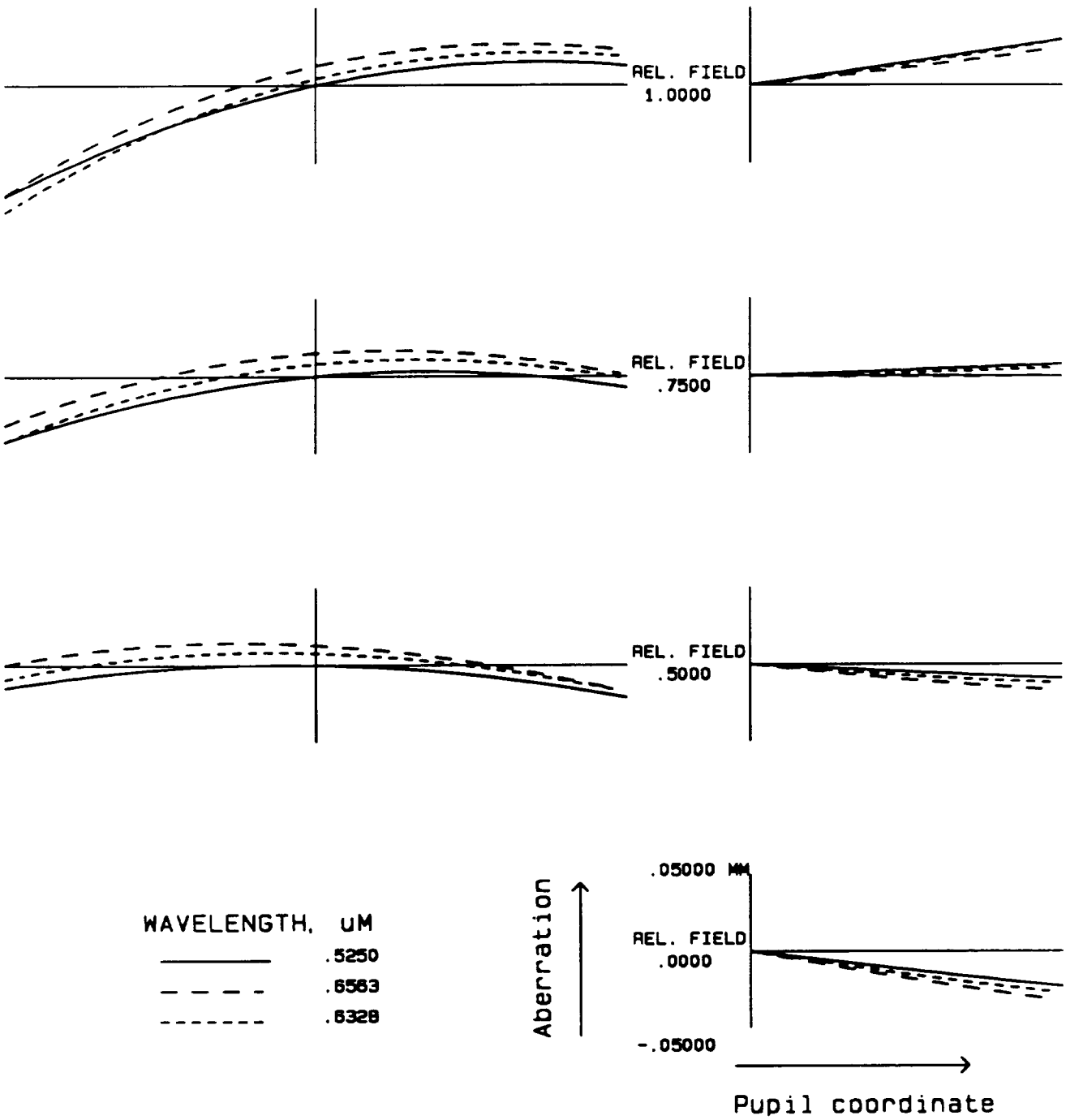


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EXVMRGLR REOPTIMIZED ORIGINAL W/ R 1147

2-Oct-92 16:31:16

TRANSVERSE ABERRATION

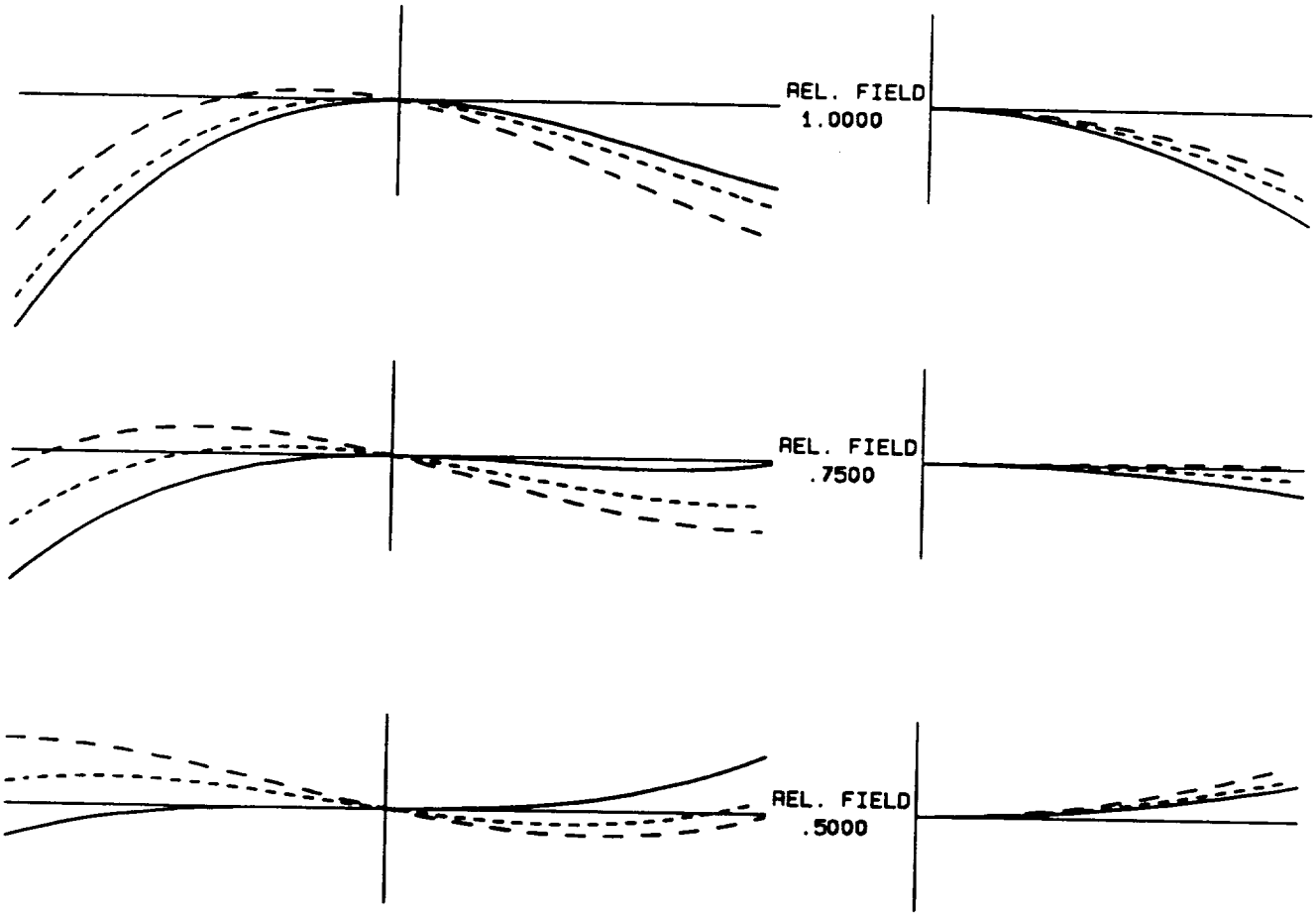


ID EXVMAGLA REOPTIMIZED ORIGINAL W/ R 1147

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 2-Oct-92 16: 32: 04

OPTICAL PATH DIFFERENCE

TANGENTIAL FAN SAGITTAL FAN

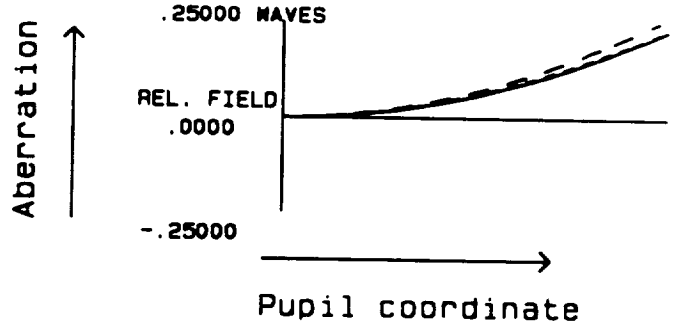


WAVELENGTH, uM

———— .5250

– – – – .6563

------- .6328



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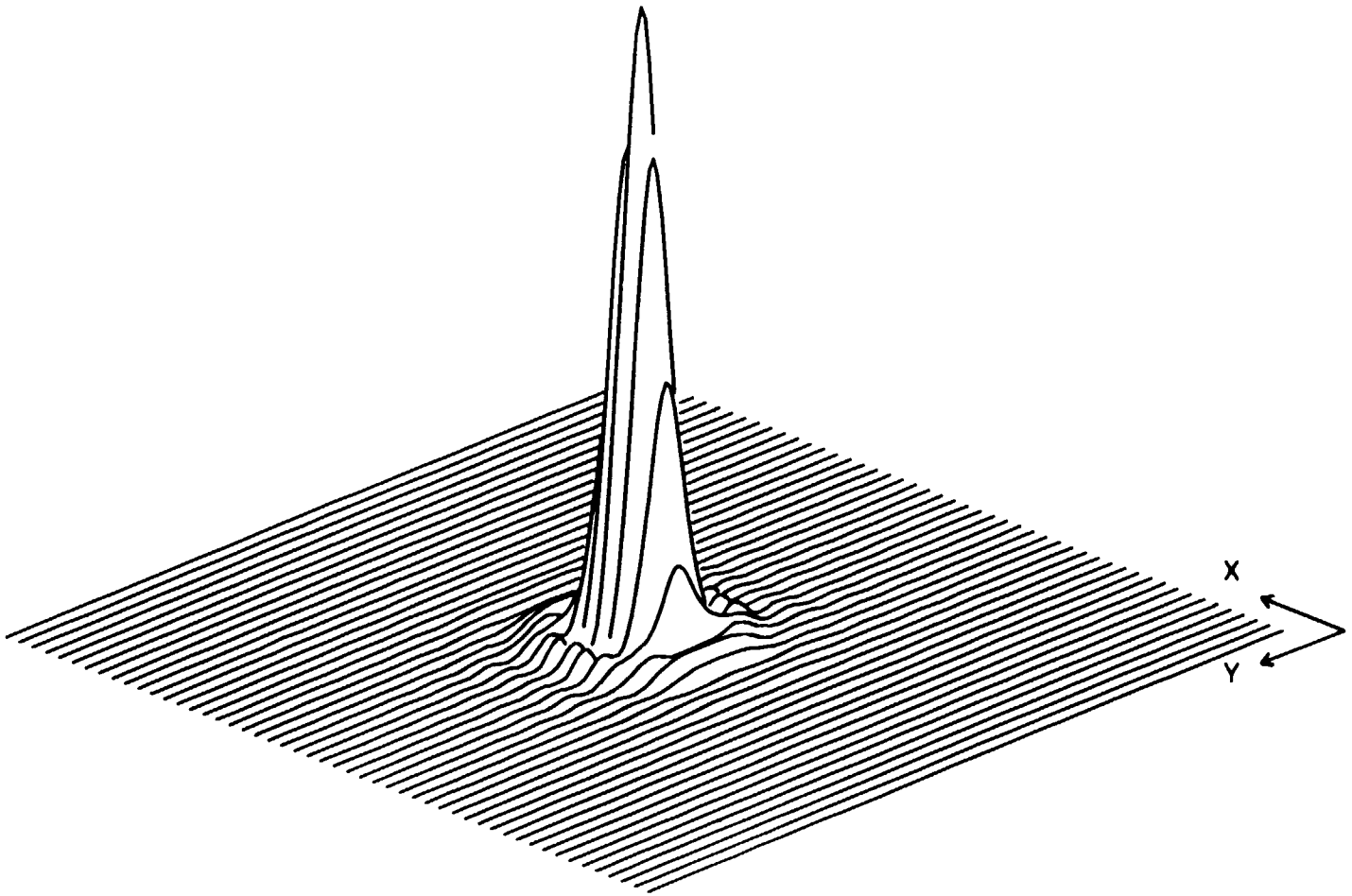
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 2-Oct-92 16:31:35

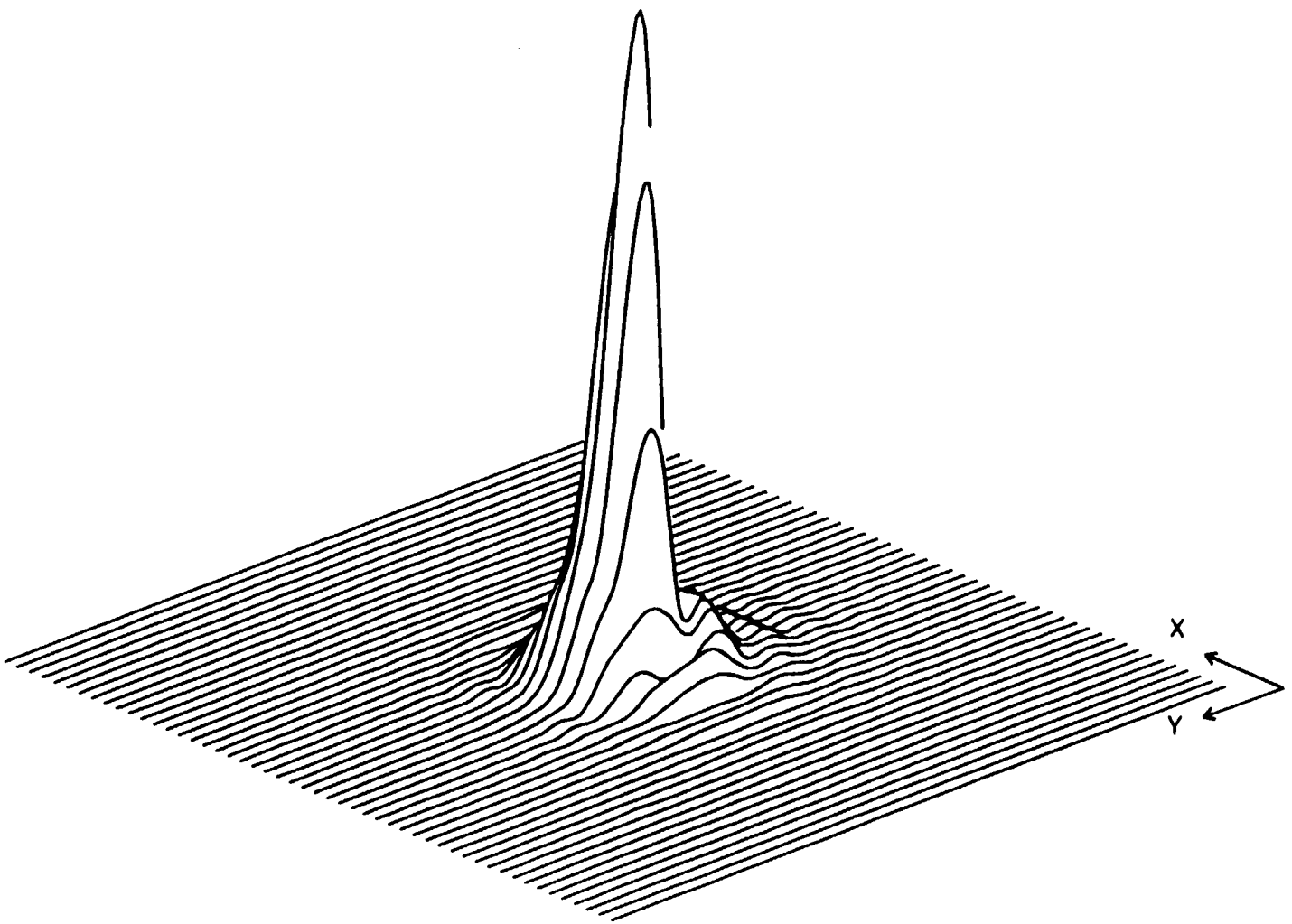
DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .031291 MM ID EXVMAGLR REOPTIMIZED ORIGINAL W/ R1147
PSPRD 2 0. 300 0 0.WAVELENGTH .52502
FRACTIONAL FIELD .0000 .0000
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

3-Oct-93 15:39:55

DIFFRACTION INTENSITY PATTERN

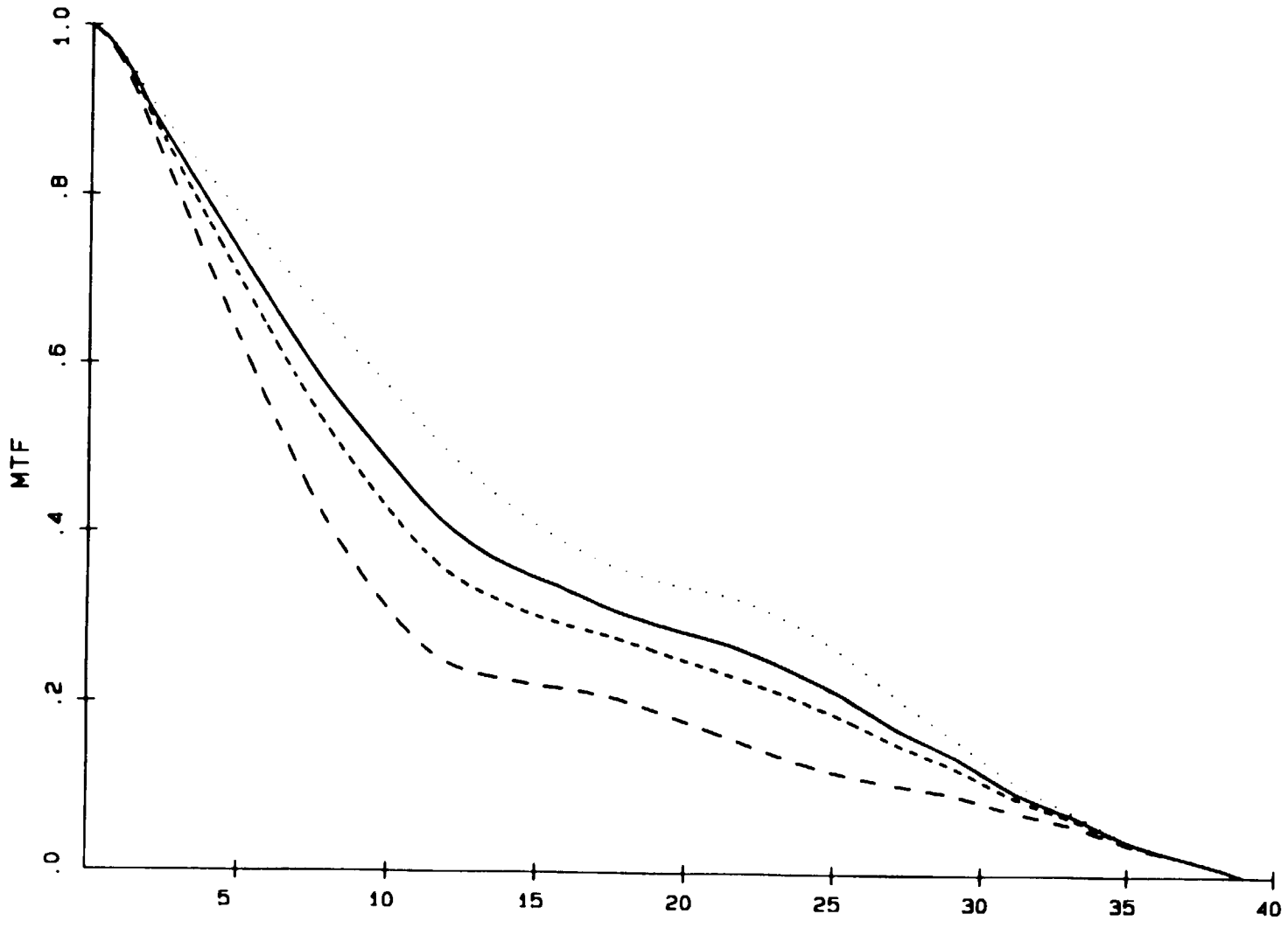


AIRY DISK RADIUS .030899 MM ID EXVMRGLR REOPTIMIZED ORIGINAL W/ R1147
PSPRD 2 1. 300 0 0.WAVELENGTH .52502
FRACTIONAL FIELD 1.0000 .0000
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

2-Oct-92 16:28:50

MODULATION TRANSFER FUNCTION

DIFF. LIM.			WAVELENGTH	WEIGHT
TAN.	.0000 FIELD	1.0000 FIELD	.52502	1.000
SAG.				



ID EXVMAGLA REOPTIMIZED ORIGINAL W/ R 1147 DEFOCUS -2.357537

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

22-Oct-92 15:15:07

APPENDIX C

BVM Design 30F
with 30 cm Telescope &
Fabry-Perot Filter

spe

LENS SPECIFICATION
ID EX1

OBJ. DIST.	INFINITE	FOCAL LENGTH	-14865.2076
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	103.0311
MARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	106.0675
CHIEF RAY HEIGHT	-.9265	OVERALL LENGTH	2127.6897
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0817	EXIT PUPIL POS.	-14.0230
F/NUMBER	-48.7704	GAUSSIAN IM. HT.	-20.6533

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION .144893E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOTT
2	INFINITE	650.00000	AIR		
3	-2394.73740	-877.23980	-AIR		
CONIC B	-.239474E+14				
AXES A	.239474E+09				
		CC	-.100000E+01		
4	-858.24060	1453.64940	AIR		
CONIC B	.470171E+03				
AXES A	-.635232E+03				
		CC	-.282538E+01		
5	718.39000	4.00000	SF8	1.69736T	358.07 SCHOTT
6	92.73000	6.60000	SSK4	1.62192T	598.46 SCHOTT
7	-128.08000	50.00000	AIR		
8	INFINITE	7.00000	BK7	1.51987T	678.41 SCHOTT
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	50.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-16.50000	-AIR		
20	-210.75000	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63000	-203.16604	-AIR		
23	141.25000	-4.80000	SF5	-1.68067T	368.78 SCHOTT
24	47.31500	-3.00000	BK7	-1.51987T	678.41 SCHOTT
25	-61.74800	-26.57130	-AIR		
26	INFINITE	-.00010	BK7	-1.51987T	678.41 SCHOTT
27	INFINITE	-48.00000	-AIR		
28	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSUAL
29	INFINITE	-48.00000	-AIR		
30	INFINITE	-.00010	BK7	-1.51987T	678.41 SCHOTT
31	INFINITE	-65.00000	-AIR		
32A	INFINITE	.00000	AIR		

33A	INFINITE	47.01663	AIR			
34	188.36000	12.50000	BK7	1.51987T	678.41	SCHOTT
35	-139.24000	6.00000	SF5	1.68067T	368.78	SCHOTT
36	-415.67000	180.84345	AIR			
37	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
38	INFINITE	12.00000	AIR			
39	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
40	INFINITE	.00028	AIR			
41	INFINITE	18.00000	FUSILICA	1.46104T	712.58	UNUSUAL
42	INFINITE	.00000	AIR			
43	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
44	INFINITE	12.00000	AIR			
45	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
46	INFINITE	102.59522	AIR			
47	673.17000	6.00000	SF5	1.68067T	368.78	SCHOTT
48	222.27000	10.00000	BK7	1.51987T	678.41	SCHOTT
49	-302.87000	364.20508	AIR			
50	121.71195	3.80000	BK7	1.51987T	678.41	SCHOTT
51	-89.71796	2.50000	SF5	1.68067T	368.78	SCHOTT
52	-268.15906	286.29516	AIR			
53	153.87200	10.10000	BK7	1.51987T	678.41	SCHOTT
54	-153.87200	43.36744	AIR			
55A	INFINITE	.00000	-AIR			
56A	INFINITE	-88.68000	-AIR			
57A	INFINITE	.00000	AIR			
58A	INFINITE	80.00000	AIR			
59	64.04000	4.80000	SK11	1.56737T	650.90	SCHOTT
60	-44.88000	2.00000	SF5	1.68067T	368.78	SCHOTT
61	-182.72000	25.67235	AIR			
62A	INFINITE	.00000	-AIR			
63A	INFINITE	-59.39900	-AIR			
64A	INFINITE	.00000	AIR			
65A	INFINITE	103.03107	AIR			
66	INFINITE	3.03647	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

TILTS AND DECENTERS ALPHA,BETA,GAMMA,AXIS
X-DECN,YDECN,ZDECN

18	TDC	70	SURFACES	
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
19	TDC	70	SURFACES	
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
32	TDC	50	SURFACES	
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
33	TDC	50	SURFACES	
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
55	TDC	30	SURFACES	
-.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
56	TDC	30	SURFACES	
-.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		

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     .000000E+00        .000000E+00        .000000E+00
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     .450000E+02        .000000E+00        .000000E+00        .000000E+00
     .000000E+00        .000000E+00        .000000E+00
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     .450000E+02        .000000E+00        .000000E+00        .000000E+00
     .000000E+00        .000000E+00        .000000E+00
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     .450000E+02        .000000E+00        .000000E+00        .000000E+00
     .000000E+00        .000000E+00        .000000E+00
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    -.450000E+02        .000000E+00        .000000E+00        .000000E+00
     .000000E+00        .000000E+00        .000000E+00
    65      TDC    20  SURFACES
    -.450000E+02        .000000E+00        .000000E+00        .000000E+00
     .000000E+00        .000000E+00        .000000E+00
SYNOPSYS AI>cap


CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

     1      153.327
     2      153.327
     3      152.407
     4      42.0432
     5      20.0000      USER-ENTERED CAO
     6      20.0000      USER-ENTERED CAO
     7      20.0000      USER-ENTERED CAO
     8      12.2786
     9      12.5000      USER-ENTERED CAO
    10      12.5000      USER-ENTERED CAO
    11      12.5000      USER-ENTERED CAO
    12      12.5000      USER-ENTERED CAO
    13      12.5000      USER-ENTERED CAO
    14      12.5000      USER-ENTERED CAO
    15      12.5000      USER-ENTERED CAO
    16      12.5000      USER-ENTERED CAO
    17      10.0840
    18      12.2925
    19      8.39924
    20      15.0000      USER-ENTERED CAO
    21      15.0000      USER-ENTERED CAO
    22      15.0000      USER-ENTERED CAO
    23      15.7500      USER-ENTERED CAO
    24      15.7500      USER-ENTERED CAO
    25      15.7500      USER-ENTERED CAO
    26      11.4836
    27      11.4836
    28      16.4827
    29      17.1580
    30      22.1571
    31      22.1571
    32      45.6645
    33      28.9268
    34      40.0000      USER-ENTERED CAO
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    35      40.0000      USER-ENTERED CAO
    36      40.0000      USER-ENTERED CAO
    37      45.0000      USER-ENTERED CAO
    38      32.7176
    39      55.0000      USER-ENTERED CAO
    40      32.5578
    41      37.0000      USER-ENTERED CAO
    42      32.6078
    43      55.0000      USER-ENTERED CAO
    44      32.6661
    45      45.0000      USER-ENTERED CAO
    46      32.7259
    47      40.0000      USER-ENTERED CAO
    48      40.0000      USER-ENTERED CAO
    49      40.0000      USER-ENTERED CAO
    50      10.1600      USER-ENTERED CAO
    51      10.1600      USER-ENTERED CAO
    52      10.1600      USER-ENTERED CAO
    53      33.0000      USER-ENTERED CAO
    54      33.0000      USER-ENTERED CAO
    55      31.0590
    56      20.9605
    57      25.0669
    58      16.9167
    59      13.2500      USER-ENTERED CAO
    60      13.2500      USER-ENTERED CAO
    61      13.2500      USER-ENTERED CAO
    62      13.9579
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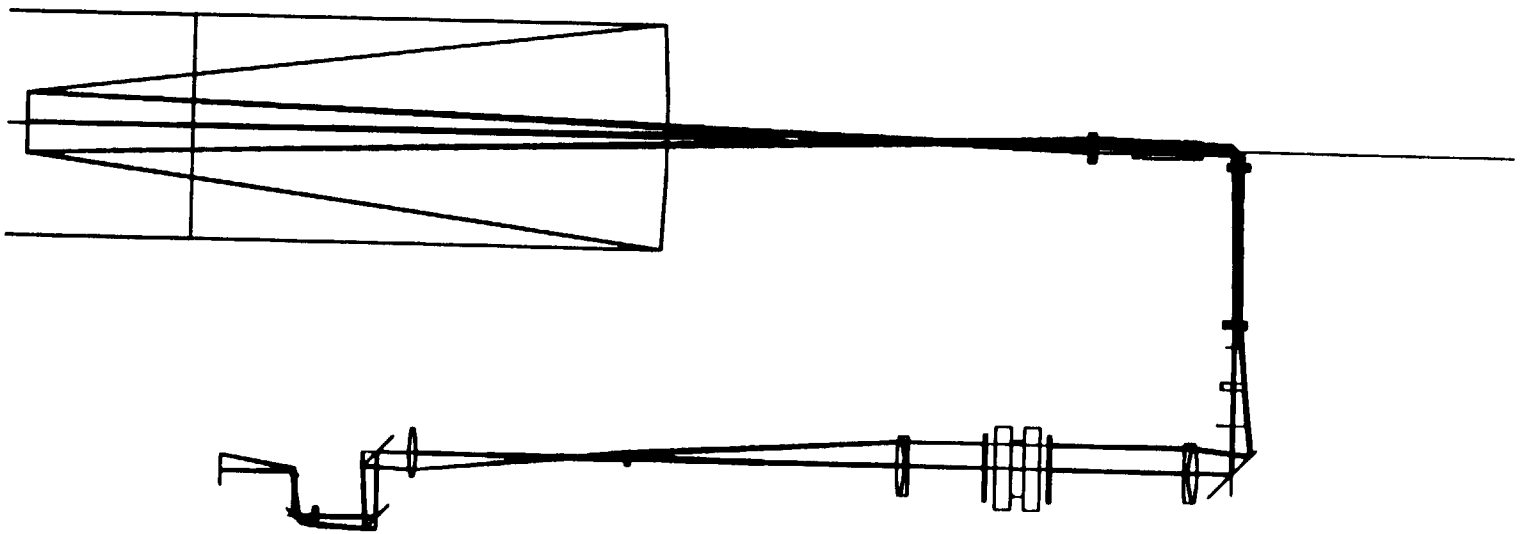
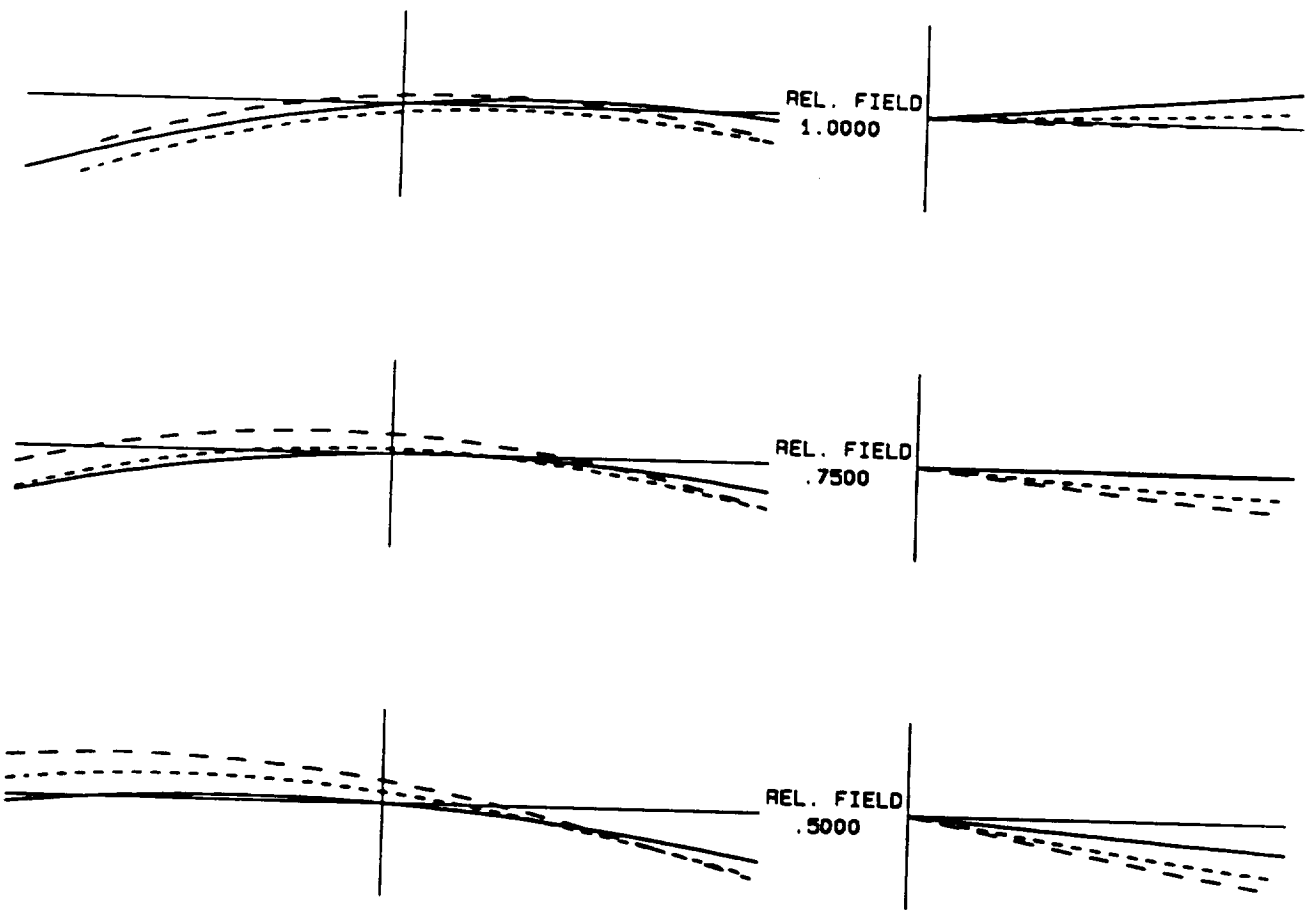
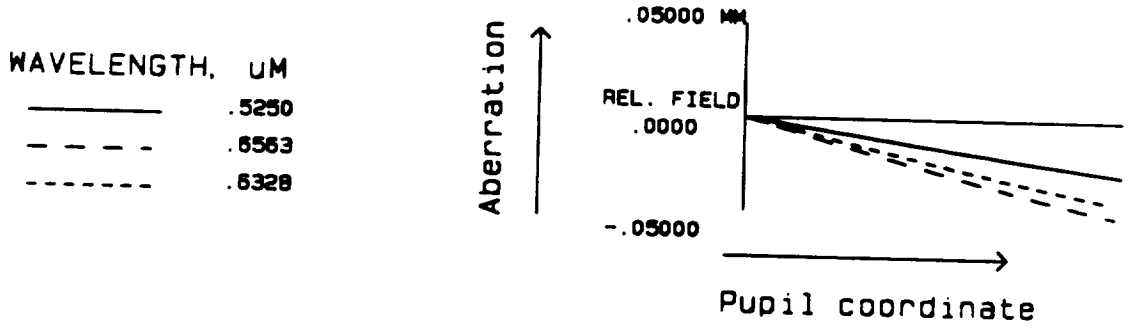


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EX1

7-Apr-92 11:30:14

TRANSVERSE ABERRATION





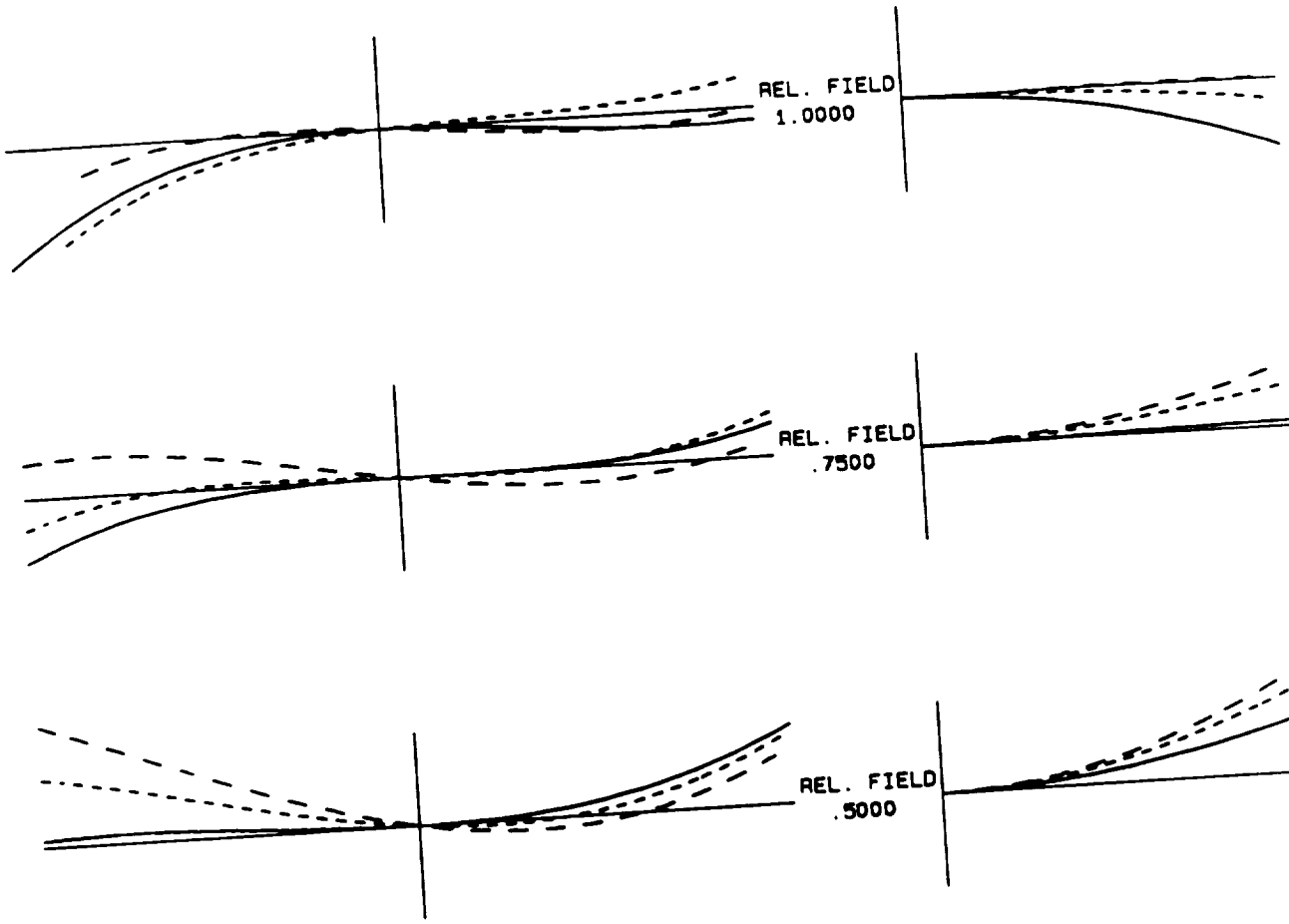
ID EX1

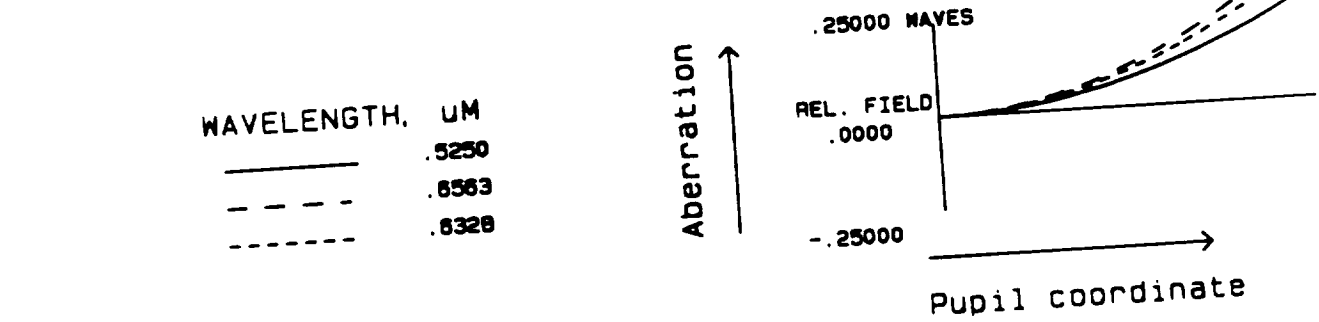
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 7-Apr-92 11:32:10

OPTICAL PATH DIFFERENCE

TANGENTIAL FAN

SAGITTAL FAN

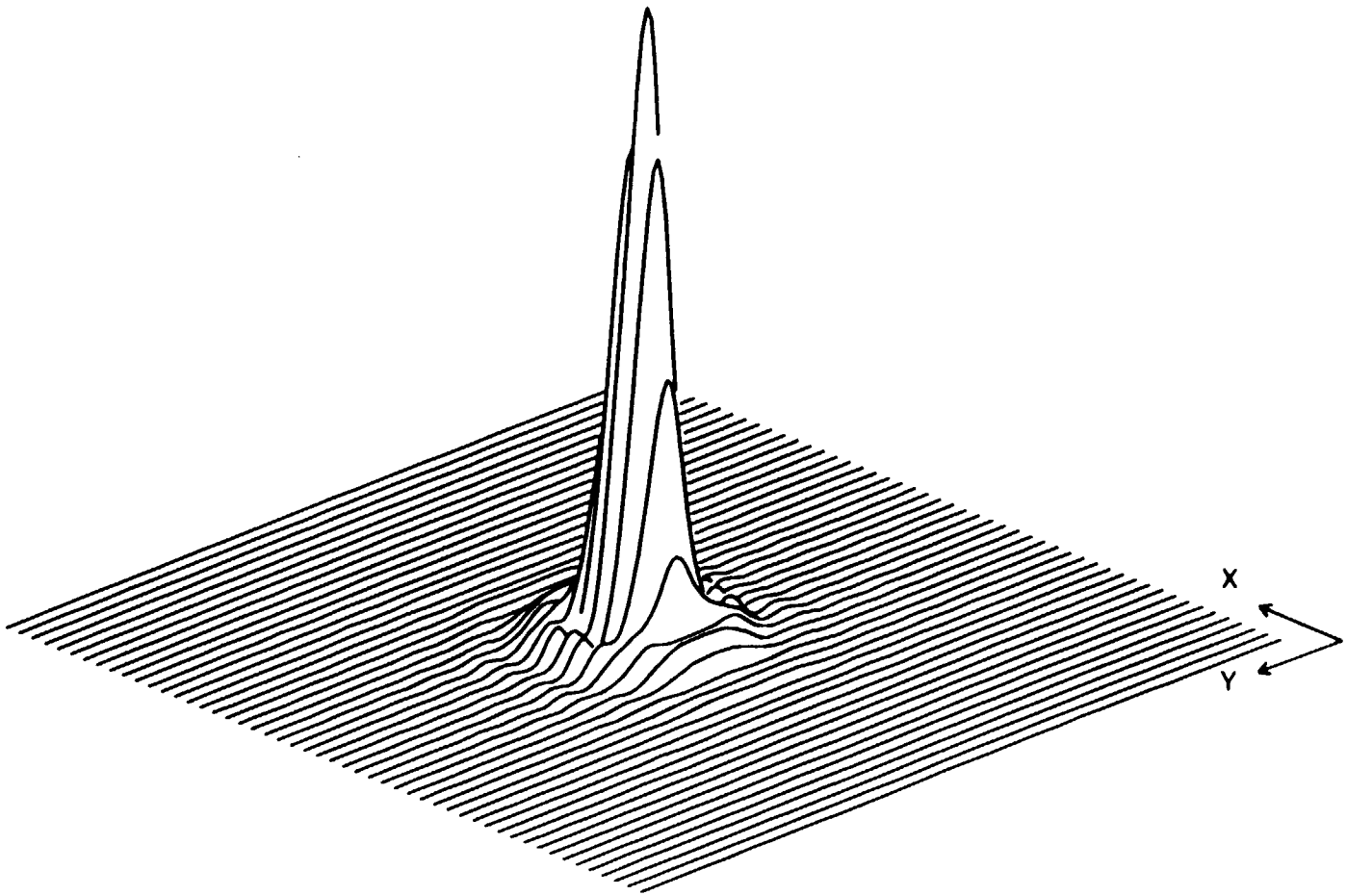




ID EX1

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 7-Apr-92 11:30:52

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .031230 MM ID EX1

PSPRD 2 0. 300 0 0. WAVELENGTH .52502

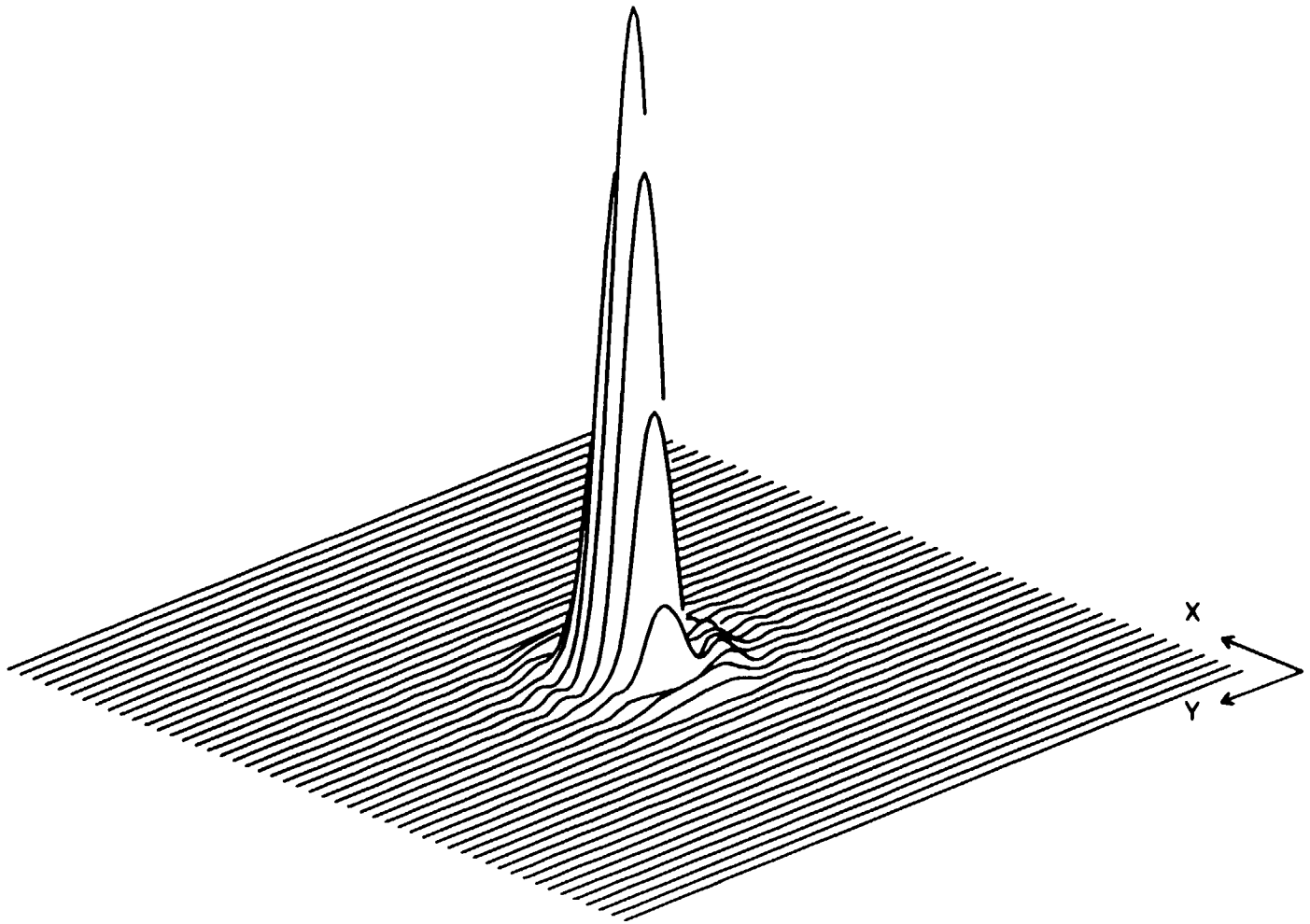
FRACTIONAL FIELD .0000 .0000

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

1147

7-Apr-92 11:33:23

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .030963 MM ID EX1

PSPRD 2 1. 300 0 0. WAVELENGTH .52502

FRACTIONAL FIELD 1.0000 .0000

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

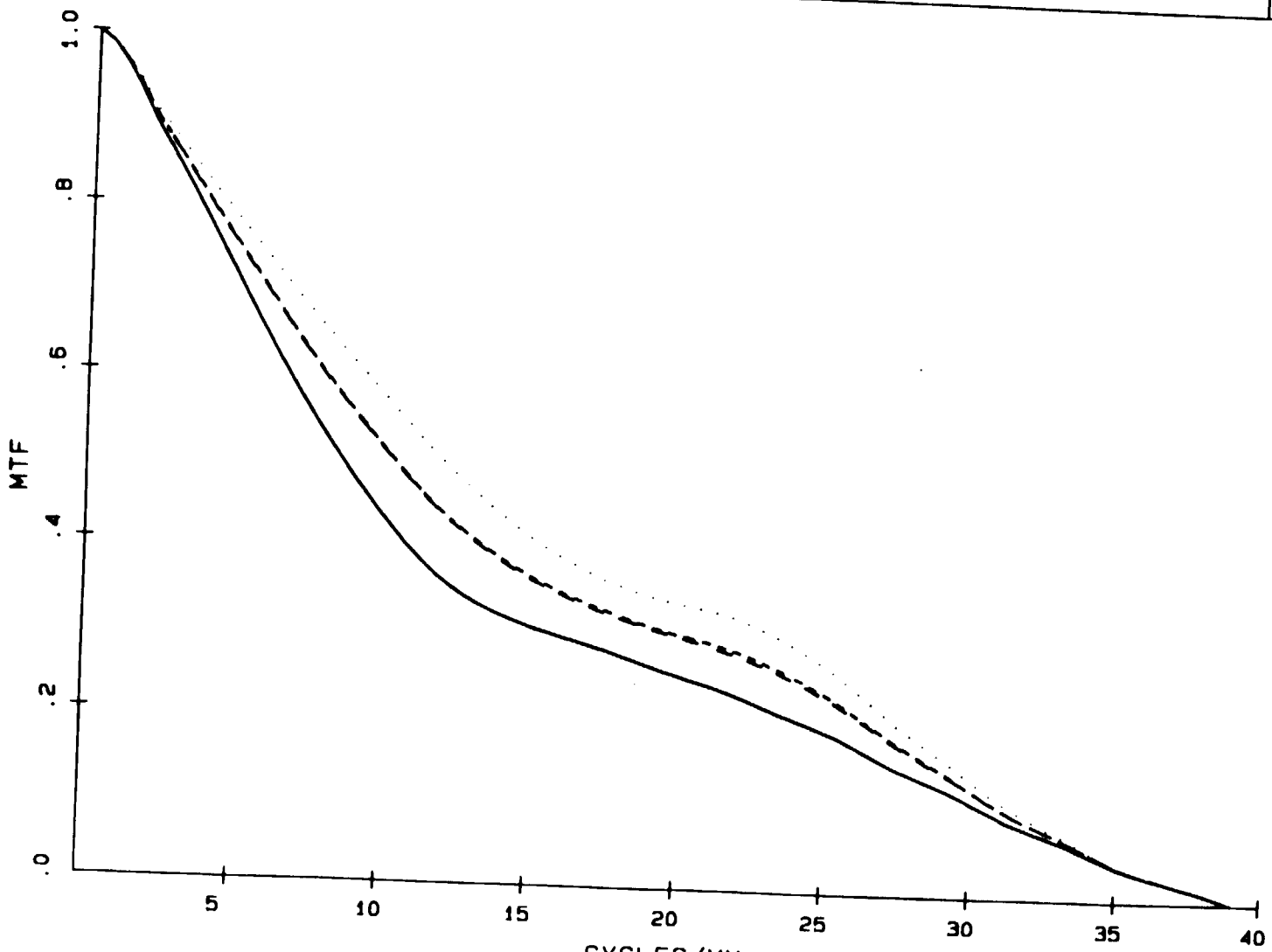
1147

7-Apr-92 11:34:34

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. . . . . .0000 FIELD 1.0000 FIELD
SAG. . . . . .

WAVELENGTH	WEIGHT
.52502	1.000



ID EX1
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM
1147
DEFOCUS -3.036473

22-Oct-92 15:16:23

spe

LENS SPECIFICATION
ID EX1-2X

1147

OBJ. DIST.	INFINITE	FOCAL LENGTH	-27765.8014
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	103.0311
MARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	105.8447
CHIEF RAY HEIGHT	-.4634	OVERALL LENGTH	2127.6897
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0408	EXIT PUPIL POS.	-10.1772
F/NUMBER	-91.0951	GAUSSIAN IM. HT.	-19.3160

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION .270925E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOTT
2	INFINITE	650.00000	AIR		
3	-2394.73740	-877.23980	-AIR		
CONIC B	-.239474E+14				
AXES A	.239474E+09	CC	-.100000E+01		
4	-858.24060	1453.64940	AIR		
CONIC B	.470171E+03				
AXES A	-.635232E+03	CC	-.282538E+01		
5	718.39000	4.00000	SF8	1.69736T	358.07 SCHOTT
6	92.73000	6.60000	SSK4	1.62192T	598.46 SCHOTT
7	-128.08000	50.00000	AIR		
8	INFINITE	7.00000	BK7	1.51987T	678.41 SCHOTT
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	50.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-16.50000	-AIR		
20	-210.75000	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63000	-60.00000	-AIR		
23	-120.15000	-5.21000	BK7	-1.51987T	678.41 SCHOTT
24	76.21000	-2.90000	SF5	-1.68067T	368.78 SCHOTT
25	201.90000	-58.03881	-AIR		
26	75.53100	-3.20000	SF5	-1.68067T	368.78 SCHOTT
27	24.40600	-1.50000	BK7	-1.51987T	678.41 SCHOTT
28	-30.28700	130.84881G	-AIR		
29	INFINITE	-203.16604	-AIR		
30	141.25000	-4.80000	SF5	-1.68067T	368.78 SCHOTT
31	47.31500	-3.00000	BK7	-1.51987T	678.41 SCHOTT
32	-61.74800	-26.57130	-AIR		

33	INFINITE	-.00010	BK7	-1.51987T	678.41	SCHOTT
34	INFINITE	-48.00000	-AIR			
35	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58	UNUSUAL
36	INFINITE	-48.00000	-AIR			
37	INFINITE	-.00010	BK7	-1.51987T	678.41	SCHOTT
38	INFINITE	-65.00000	-AIR			
39A	INFINITE	.00000	AIR			
40A	INFINITE	47.01663	AIR			
41	188.36000	12.50000	BK7	1.51987T	678.41	SCHOTT
42	-139.24000	6.00000	SF5	1.68067T	368.78	SCHOTT
43	-415.67000	180.84345	AIR			
44	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
45	INFINITE	12.00000	AIR			
46	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
47	INFINITE	.00028	AIR			
48	INFINITE	18.00000	FUSILICA	1.46104T	712.58	UNUSUAL
49	INFINITE	.00000	AIR			
50	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
51	INFINITE	12.00000	AIR			
52	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
53	INFINITE	102.59522	AIR			
54	673.17000	6.00000	SF5	1.68067T	368.78	SCHOTT
55	222.27000	10.00000	BK7	1.51987T	678.41	SCHOTT
56	-302.87000	364.20508	AIR			
57	121.71195	3.80000	BK7	1.51987T	678.41	SCHOTT
58	-89.71796	2.50000	SF5	1.68067T	368.78	SCHOTT
59	-268.15906	286.29516	AIR			
60	153.87200	10.10000	BK7	1.51987T	678.41	SCHOTT
61	-153.87200	43.36744	AIR			
62A	INFINITE	.00000	-AIR			
63A	INFINITE	-88.68000	-AIR			
64A	INFINITE	.00000	AIR			
65A	INFINITE	80.00000	AIR			
66	64.04000	4.80000	SK11	1.56737T	650.90	SCHOTT
67	-44.88000	2.00000	SF5	1.68067T	368.78	SCHOTT
68	-182.72000	25.67235	AIR			
69A	INFINITE	.00000	-AIR			
70A	INFINITE	-59.39900	-AIR			
71A	INFINITE	.00000	AIR			
72A	INFINITE	103.03107	AIR			
73	INFINITE	2.81362	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

TILTS AND DECENTERS ALPHA,BETA,GAMMA,AXIS
X-DECN,YDECN,ZDECN

18 TDC 70 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00
19 TDC 70 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00
29 COINCIDENT WITH SURFACE 22
39 TDC 50 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00
40 TDC 50 SURFACES

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    .000000E+00     .000000E+00     .000000E+00
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   -.450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   63      TDC    30  SURFACES
   -.450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   64      TDC    30  SURFACES
    .450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   65      TDC    30  SURFACES
    .450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   69      TDC    20  SURFACES
    .450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   70      TDC    20  SURFACES
    .450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   71      TDC    20  SURFACES
   -.450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
   72      TDC    20  SURFACES
   -.450000E+02     .000000E+00     .000000E+00     .000000E+00
    .000000E+00     .000000E+00     .000000E+00
SYNOPSYS AI>cap


CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

    1      152.863
    2      152.863
    3      152.403
    4      41.4157
    5      20.0000      USER-ENTERED CAO
    6      20.0000      USER-ENTERED CAO
    7      20.0000      USER-ENTERED CAO
    8      9.37177
    9      12.5000      USER-ENTERED CAO
   10      12.5000      USER-ENTERED CAO
   11      12.5000      USER-ENTERED CAO
   12      12.5000      USER-ENTERED CAO
   13      12.5000      USER-ENTERED CAO
   14      12.5000      USER-ENTERED CAO
   15      12.5000      USER-ENTERED CAO
   16      12.5000      USER-ENTERED CAO
   17      8.28229
   18      10.7094
   19      7.44603
   20      15.0000      USER-ENTERED CAO
   21      15.0000      USER-ENTERED CAO
   22      15.0000      USER-ENTERED CAO
   23      15.0000      USER-ENTERED CAO
   24      15.0000      USER-ENTERED CAO
   25      15.0000      USER-ENTERED CAO
   26      9.00000      USER-ENTERED CAO
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27	9.00000	USER-ENTERED CAO
28	9.00000	USER-ENTERED CAO
29	7.98298	
30	15.7500	USER-ENTERED CAO
31	15.7500	USER-ENTERED CAO
32	15.7500	USER-ENTERED CAO
33	9.00329	
34	9.00330	
35	13.7603	
36	14.4030	
37	19.1600	
38	19.1600	
39	40.1893	
40	25.6018	
41	40.0000	USER-ENTERED CAO
42	40.0000	USER-ENTERED CAO
43	40.0000	USER-ENTERED CAO
44	45.0000	USER-ENTERED CAO
45	30.4328	
46	55.0000	USER-ENTERED CAO
47	30.4306	
48	37.0000	USER-ENTERED CAO
49	30.4939	
50	55.0000	USER-ENTERED CAO
51	30.5678	
52	45.0000	USER-ENTERED CAO
53	30.6435	
54	40.0000	USER-ENTERED CAO
55	40.0000	USER-ENTERED CAO
56	40.0000	USER-ENTERED CAO
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63	19.6798	
64	23.7675	
65	16.1343	
66	13.2500	USER-ENTERED CAO
67	13.2500	USER-ENTERED CAO
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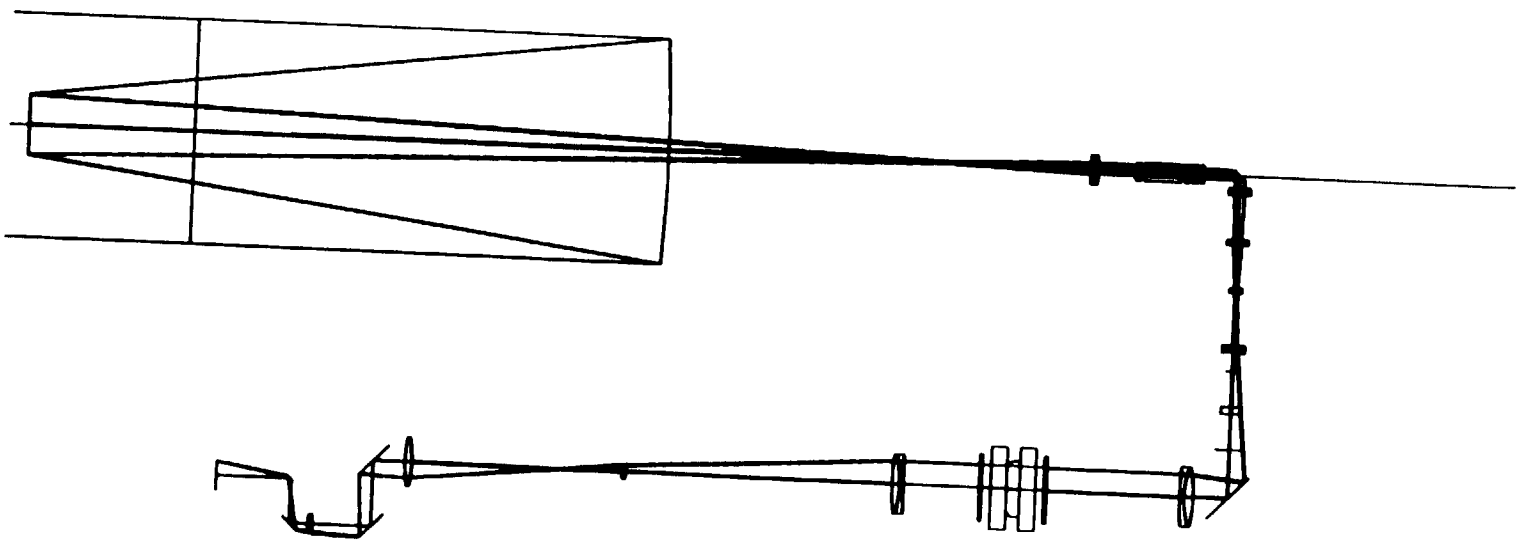
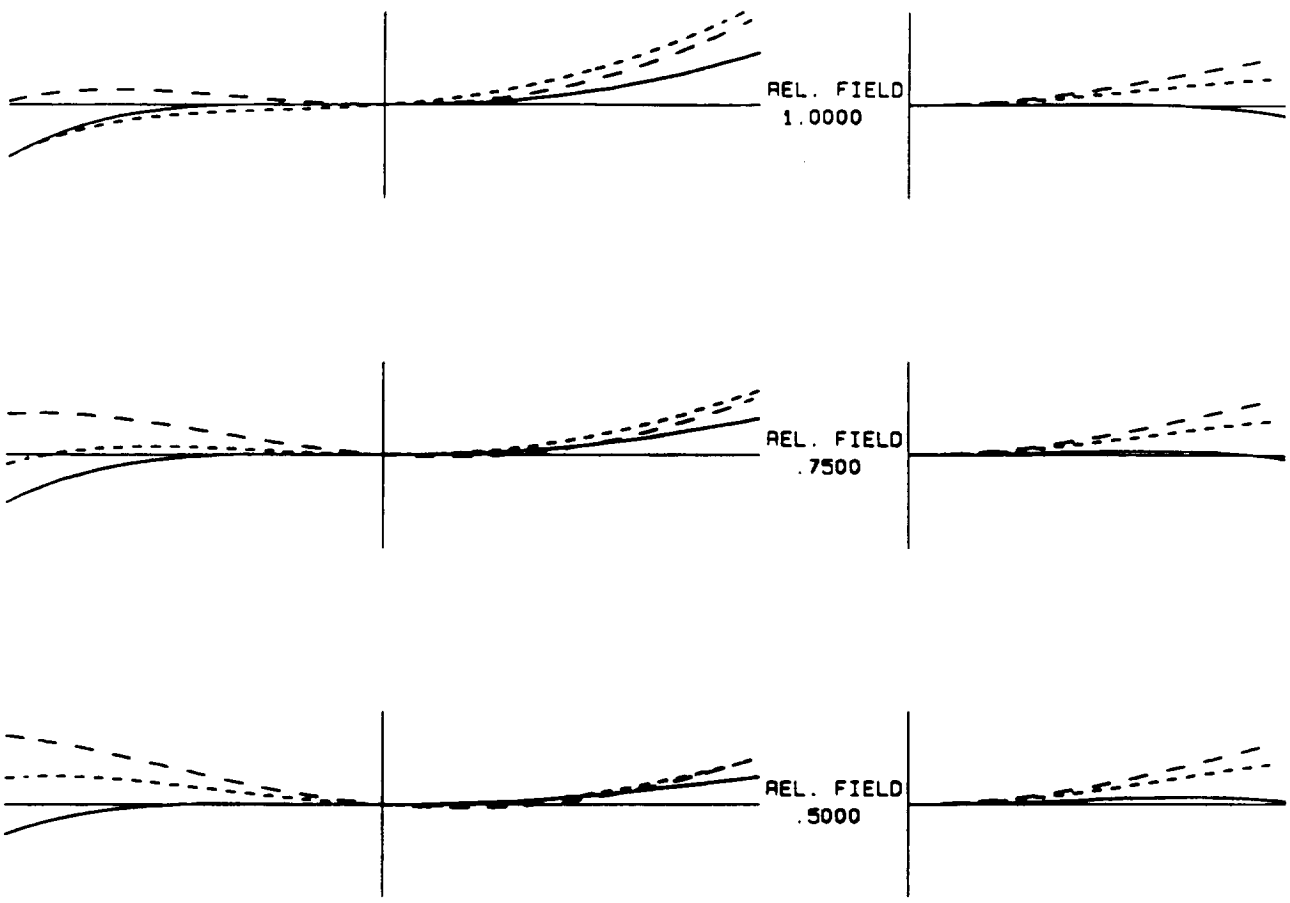
SYNOPSYS AI>

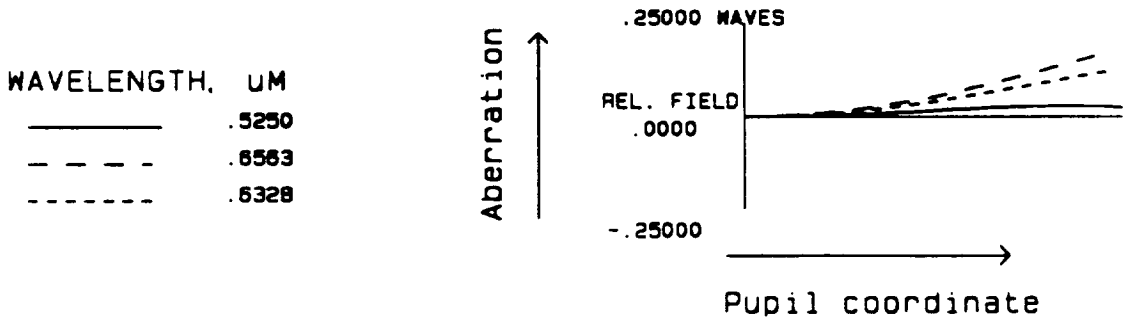


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EX1-2X

7-Apr-92 08:24:10

OPTICAL PATH DIFFERENCE





ID EX1-2X

1147

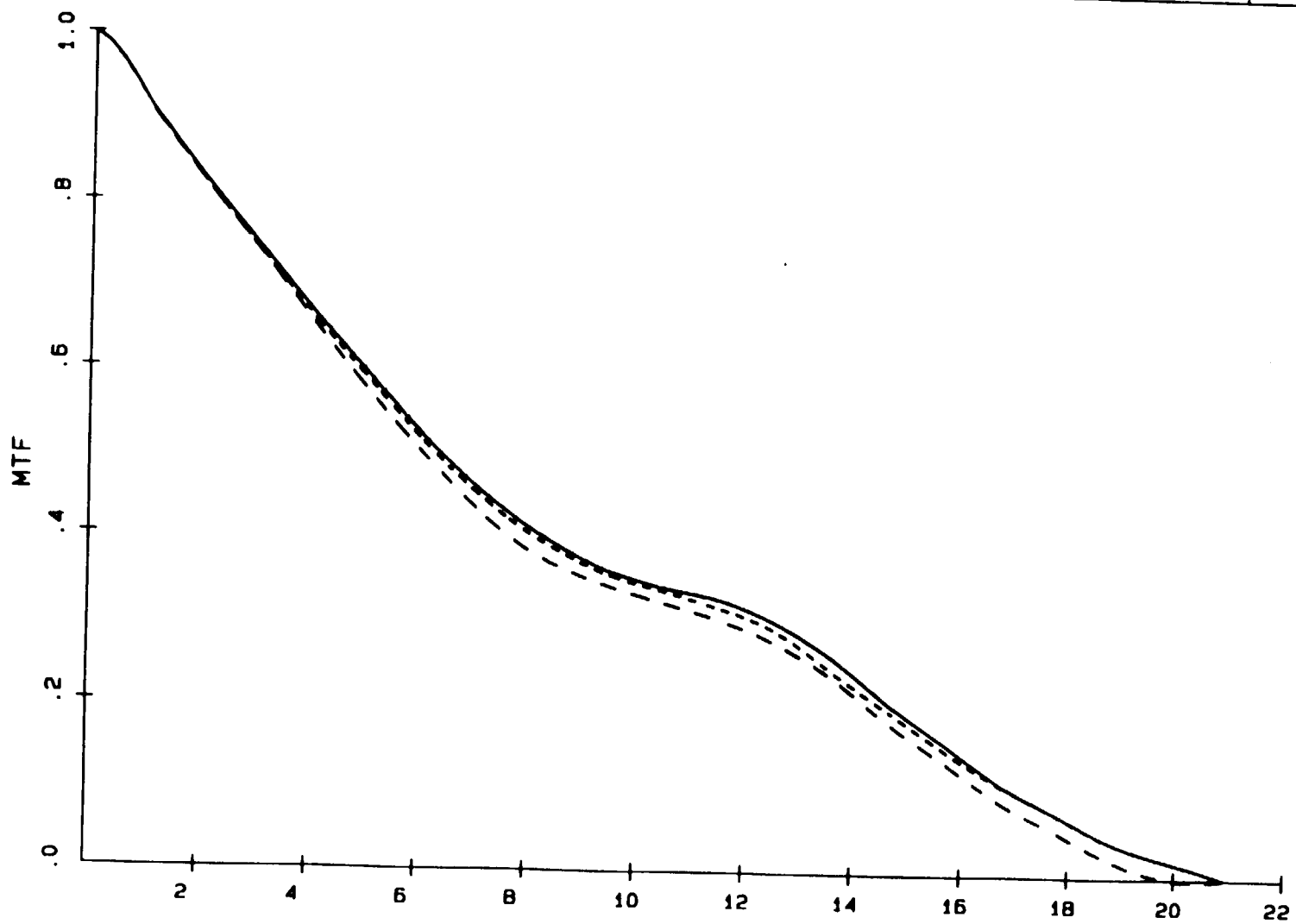
SEMI-FIELD = .0408 DEGREES SEMI-APERTURE = 152.4000 MM 7-Apr-92 08:24:59

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .....
SAG. .....

.0000 FIELD
1.0000 FIELD

WAVELENGTH	WEIGHT
.52502	1.000



ID EX1-2X
1147
SEMI-FIELD = .0408 DEGREES SEMI-APERTURE = 152.4000 MM
DEFOCUS -2.813625

22-Oct-92 15:17:38

Tolerance for EX1

```
GDS

PANT

CALL  PANT

CALL  PANT
VLIST TH 3 4 22 25 36 41 49 52
END
CALL  AANT
GNV 0 1 4 2

***      26 RAYS GENERATED IN COLOR      2 AT HBAR       .0000 GBAR       .0000

END
CALL  TOL 1.13933E-02


TOLERANCE CALCULATIONS
CRITERION ON ABERRATIONS      .011393


VARIABLE LIST
NO.   SN   PAR                UPPER LIMIT      LOWER LIMIT        INCREMENT
 1     3    TH       .00000000E+00    -.10000000E+05     .10000000E-02
 2     4    TH       .10000000E+05     .00000000E+00     .10000000E-02
 3    22    TH       .00000000E+00    -.10000000E+05     .10000000E-02
 4    25    TH       .00000000E+00    -.10000000E+05     .10000000E-02
 5    36    TH       .10000000E+05     .00000000E+00     .10000000E-02
 6    41    TH       .10000000E+05     .00000000E+00     .10000000E-02
 7    49    TH       .10000000E+05     .00000000E+00     .10000000E-02
 8    52    TH       .10000000E+05     .00000000E+00     .10000000E-02

SYSTEM ABERRATIONS
      1     .23656144E+00
      2     .12423974E+00
      3     .48109324E-01
      4     .96549395E-02
      5     .96549394E-02
      6     .48109324E-01
      7     .12423974E+00
      8     .23656144E+00
      9     .27352173E+00
     10     .16192533E+00
     11     .86302668E-01
     12     .48109324E-01
     13     .48109324E-01
     14     .86302668E-01
     15     .16192533E+00
     16     .27352173E+00
     17     .23656144E+00
     18     .16192533E+00
     19     .12423974E+00
     20     .12423974E+00
     21     .16192533E+00
     22     .23656144E+00
     23     .27352173E+00
     24     .23656144E+00
     25     .23656144E+00
     26     .27352173E+00
```

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 1  TOTAL     .75948207E-02
INITIAL MERIT FUNCTION    .576813E-04
  -.877239E+03     .697179E-04
  -.877235E+03     .137643E-03    1


TOLERANCE, PARAMETER NO.    1

  3  TH         -877.239800
  1      .117321E-01  *
EXTREME VALUE      -877.234768    TOLERANCE          -.005032

   .145362E+04     .569587E-04
   .145354E+04     .140277E-03    1


TOLERANCE, PARAMETER NO.    2

  4  TH         1453.620100
  1      .118439E-01  *
EXTREME VALUE      1453.540504    TOLERANCE           .079596

  -.203275E+03     .580013E-04
  -.203096E+03     .140118E-03    1


TOLERANCE, PARAMETER NO.    3

 22  TH         -203.276080
  1      .118371E-01  *
EXTREME VALUE      -203.095542    TOLERANCE          -.180538

  -.199656E+02     .576845E-04
  -.179313E+01     .142128E-03    1


TOLERANCE, PARAMETER NO.    4

 25  TH          -19.966645
  1      .119217E-01  *
EXTREME VALUE        -1.793129    TOLERANCE        -18.173516

   .180984E+03     .576496E-04
   .179161E+03     .140131E-03    1


TOLERANCE, PARAMETER NO.    5

 36  TH          180.982920
  1      .118377E-01  *
EXTREME VALUE       179.161158    TOLERANCE          1.821762

   .180010E+02     .576596E-04
   .153384E+02     .140128E-03    1


TOLERANCE, PARAMETER NO.    6

 41  TH          18.000000
  1      .118376E-01  *
```

```
EXTREME VALUE          15.338391    TOLERANCE          2.661609

    .379535E+03      .576660E-04
    .375754E+03      .139448E-03    1

TOLERANCE, PARAMETER NO.    7

49  TH              379.534130
 1      .118088E-01   *
EXTREME VALUE         375.754296    TOLERANCE          3.779834

    .287390E+03      .576191E-04
    .286462E+03      .140633E-03    1

TOLERANCE, PARAMETER NO.    8

52  TH              287.389160
 1      .118589E-01   *
EXTREME VALUE         286.462303    TOLERANCE           .926857

TOLERANCE SUMMARY
VAR. NO.                              VALUE        TOLERANCE  LIM. ABRN.

   1      3  TH                   -877.239800        -.005032        1
   2      4  TH                   1453.620100         .079596        1
   3     22  TH                   -203.276080        -.180538        1
   4     25  TH                    -19.966645      -18.173516        1
   5     36  TH                    180.982920        1.821762        1
   6     41  TH                     18.000000        2.661609        1
   7     49  TH                    379.534130        3.779834        1
   8     52  TH                    287.389160         .926857        1

SYNOPSYS AI>
```

APPENDIX D

BVM Design 30B
with 30 cm Telescope &
Birefringent Filter

SYNOPSYS AI> SPE
LENS SPECIFICATION
ID EB

OBJ. DIST.	INFINITE	FOCAL LENGTH	14526.5198
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	144.7178
MARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	150.6815
CHIEF RAY HEIGHT	-.9265	OVERALL LENGTH	1554.6150
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0817	EXIT PUPIL POS.	-18.4518
F/NUMBER	47.6592	GAUSSIAN IM. HT.	19.9761

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION -.140143E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOT
2	INFINITE	650.00000	AIR		
3	-2394.73740	-877.23980	-AIR		
CONIC B	-.239474E+14				
AXES A	.239474E+09	CC	-.100000E+01		
4	-858.24060	1454.48740	AIR		
CONIC B	.470171E+03				
AXES A	-.635232E+03	CC	-.282538E+01		
5	718.39000	4.00000	SF8	1.69736T	358.07 SCHOT
6	92.73000	6.60000	SSK4	1.62192T	598.46 SCHOT
7	-128.08000	50.00000	AIR		
8	INFINITE	7.00000	BK7	1.51987T	678.41 SCHOT
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSU
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSU
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOT
17	INFINITE	50.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-16.50000	-AIR		
20	-210.75000	-5.00000	BAK4	-1.57269T	607.06 SCHOT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOT
22	515.63000	-152.84491	-AIR		
23	466.59525	-2.50000	F5	-1.60947T	428.07 SCHOT
24	-26.40990	-23.51403	-AIR		
25	-228.73106	-7.64000	FK5	-1.49012T	736.70 SCHOT
26	32.60421	.00000	-AIR		
27	INFINITE	-.00010	BK7	-1.51987T	678.41 SCHOT
28	INFINITE	-48.00000	-AIR		
29	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSU
30	INFINITE	-48.00000	-AIR		
31	INFINITE	-.00010	BK7	-1.51987T	678.41 SCHOT
32	INFINITE	-25.00000	-AIR		
33A	INFINITE	.00000	AIR		
34A	INFINITE	12.50000	AIR		
35	INFINITE	300.00000	CALCITE	1.66356T	529.15 UNUSU
36	INFINITE	15.00000	AIR		
37	182.72000	2.00000	SF5	1.68067T	368.78 SCHOT
38	44.88000	4.80000	SK11	1.56737T	650.90 SCHOT

39	-64.04000	127.36551	AIR		
40	8.57632	5.00000	LF5	1.58687T	456.99 SCHOT
41	6.46007	144.71778	AIR		
42	INFINITE	5.96376	AIR		

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

TILTS AND DECENTERS ALPHA,BETA,GAMMA,AXIS
X-DECN,YDECN,ZDECN

```
  18      TDC    70  SURFACES
   .450000E+02      .000000E+00     .000000E+00     .000000E+00
   .000000E+00      .000000E+00     .000000E+00
  19      TDC    70  SURFACES
   .450000E+02      .000000E+00     .000000E+00     .000000E+00
   .000000E+00      .000000E+00     .000000E+00
  33      TDC    50  SURFACES
   .450000E+02      .000000E+00     .000000E+00     .000000E+00
   .000000E+00      .000000E+00     .000000E+00
  34      TDC    50  SURFACES
   .450000E+02      .000000E+00     .000000E+00     .000000E+00
   .000000E+00      .000000E+00     .000000E+00
SYNOPSYS AI> CAP
```

CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

1	153.327	
2	153.327	
3	152.407	
4	42.0432	
5	20.0000	USER-ENTERED CAO
6	20.0000	USER-ENTERED CAO
7	20.0000	USER-ENTERED CAO
8	12.3011	
9	12.5000	USER-ENTERED CAO
10	12.5000	USER-ENTERED CAO
11	12.5000	USER-ENTERED CAO
12	12.5000	USER-ENTERED CAO
13	12.5000	USER-ENTERED CAO
14	12.5000	USER-ENTERED CAO
15	12.5000	USER-ENTERED CAO
16	12.5000	USER-ENTERED CAO
17	10.0964	
18	12.3012	
19	8.40382	
20	15.0000	USER-ENTERED CAO
21	15.0000	USER-ENTERED CAO
22	15.0000	USER-ENTERED CAO
23	7.68945	
24	7.75147	
25	12.9102	
26	13.4797	
27	13.4099	
28	13.4099	
29	12.2619	
30	12.1064	
31	10.9584	
32	10.9584	
33	15.0110	
34	10.3605	
35	12.5000	USER-ENTERED CAO

```
   36      12.5000      USER-ENTERED CAO
   37      13.2500      USER-ENTERED CAO
   38      13.2500      USER-ENTERED CAO
   39      13.2500      USER-ENTERED CAO
   40      4.76061
   41      3.84008
   42      21.4876
SYNOPSYS AI> POF C
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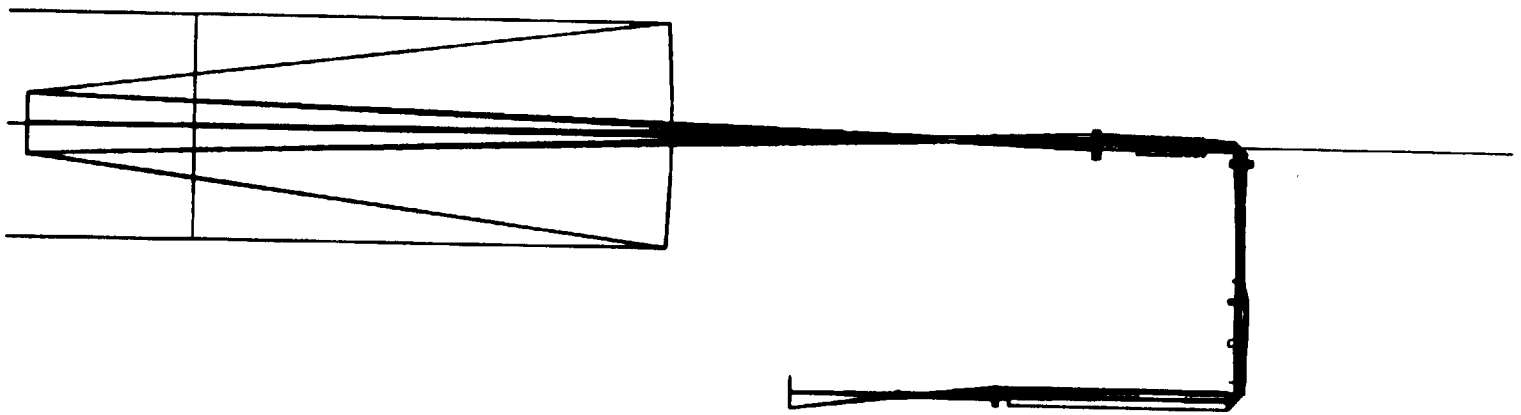
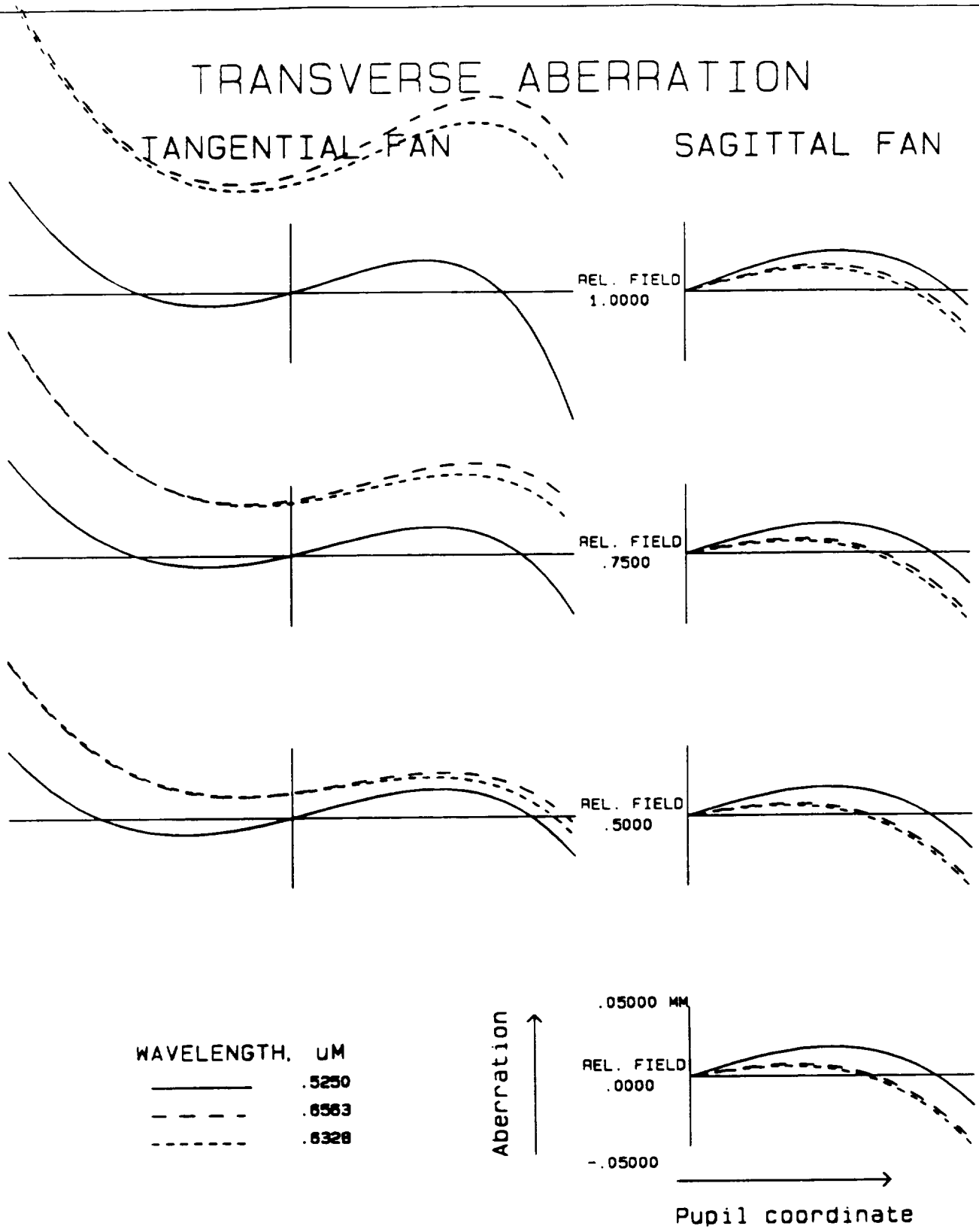


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EB

24 JUN 92 09:53:07

TRANSVERSE ABERRATION

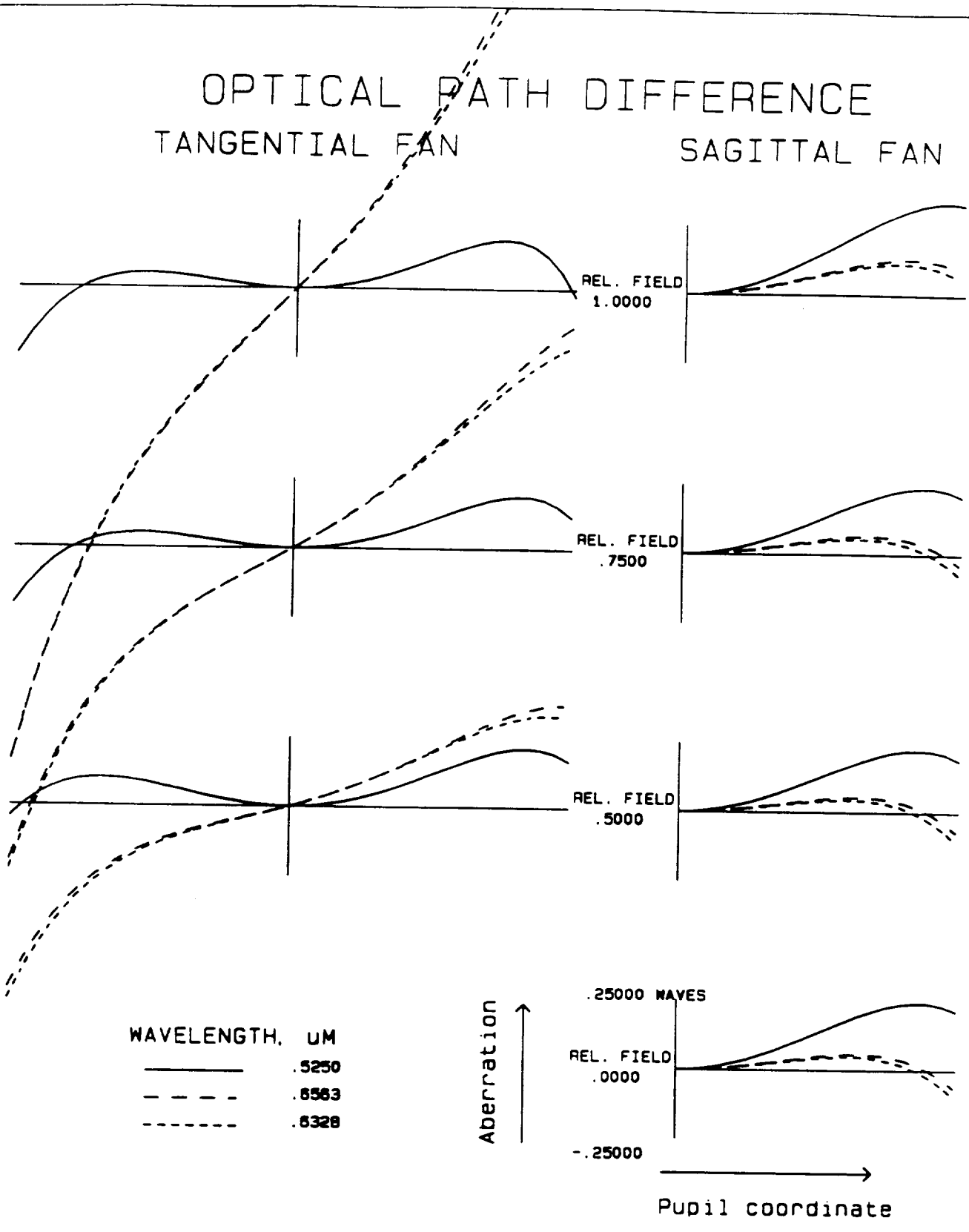


ID EB

1147

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 24-Jun-92 09:53:47

OPTICAL PATH DIFFERENCE

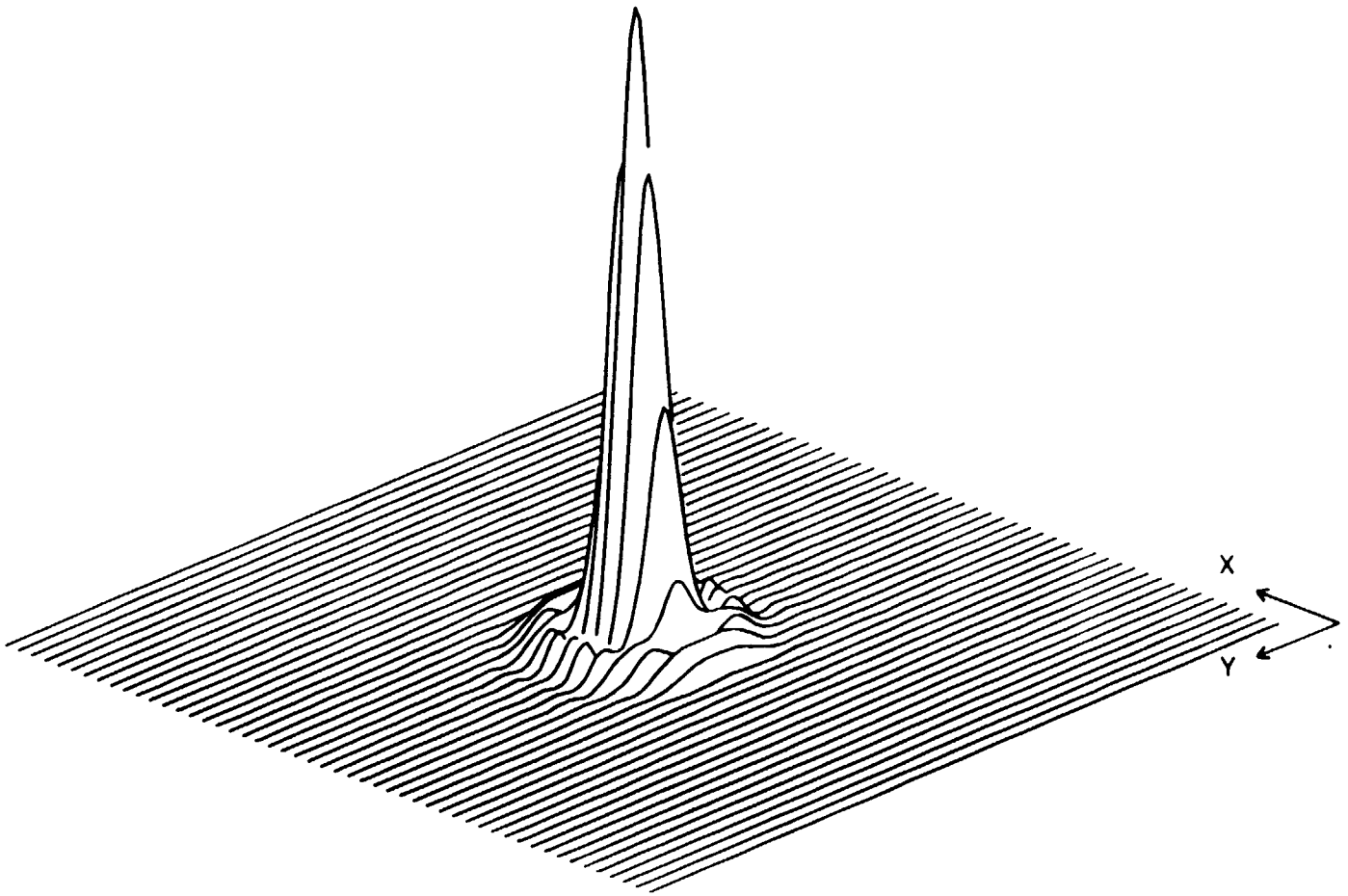


ID EB

1147

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 24-Jun-92 10:00:08

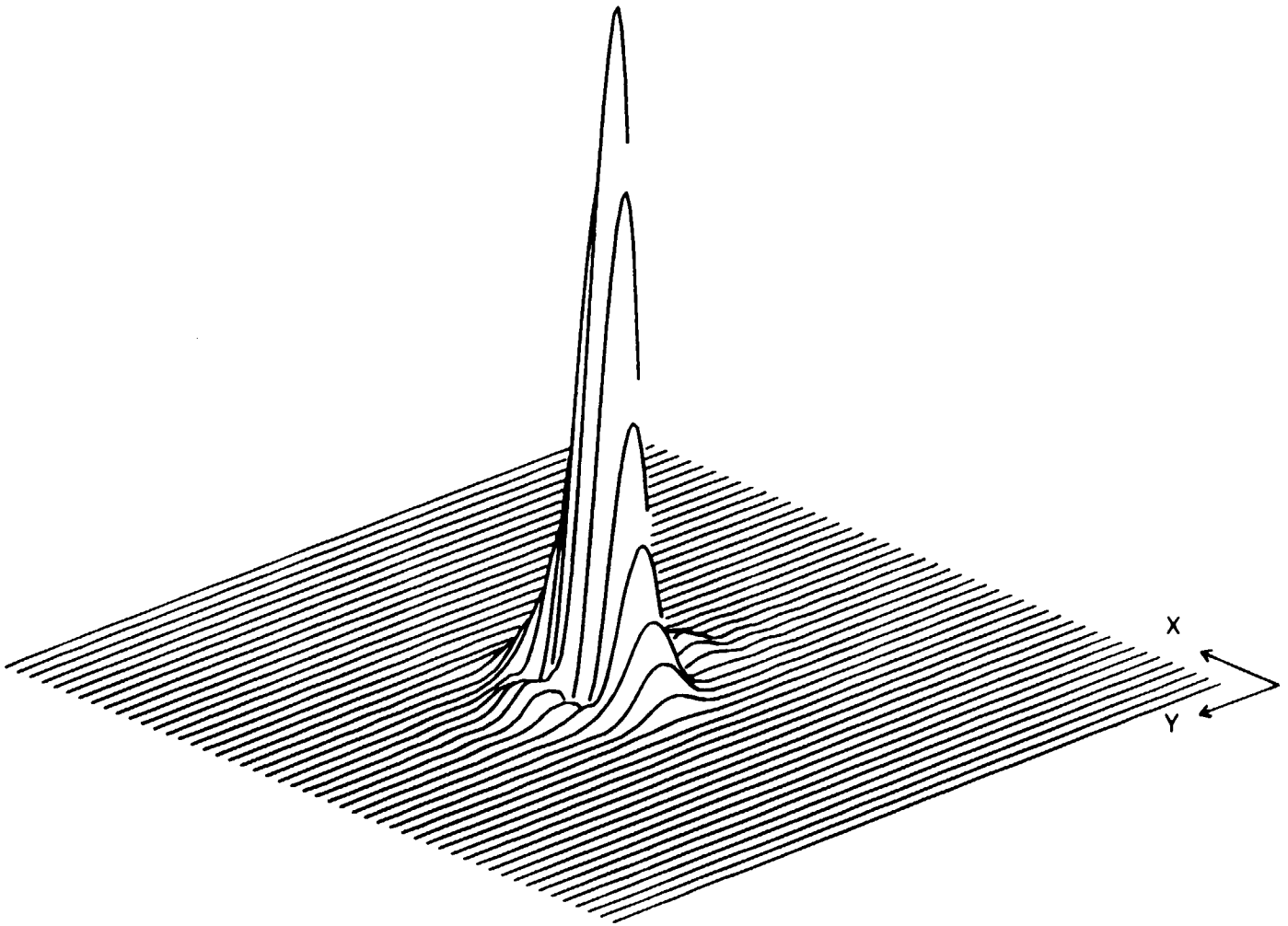
DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .030462 MM ID EB 1147
PSPRD 2 0. 300 0 0 WAVELENGTH .52502
FRACTIONAL FIELD .0000 .0000
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

24 Jun 92 10:01:40

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .037580 MM ID EB

PSPRD 2 1. 300 0 0. WAVELENGTH .52502

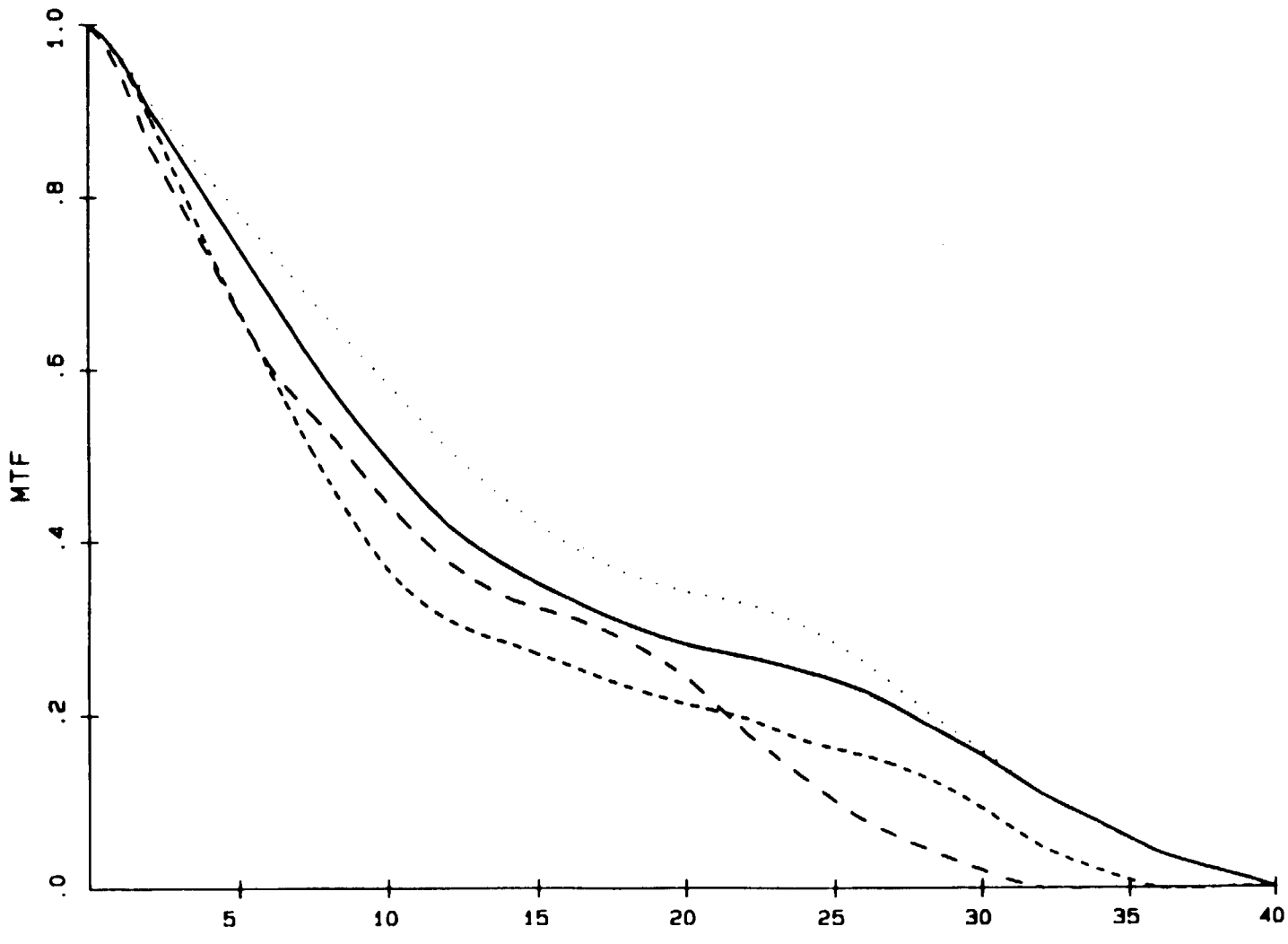
FRACTIONAL FIELD 1.0000 .0000

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

1147

MODULATION TRANSFER FUNCTION

DIFF. LIM.			WAVELENGTH	WEIGHT
TAN.	.0000 FIELD	1.0000 FIELD	.52502	1.000
SAG.				



ID EB 1147 DEFOCUS -5.963758

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

22-Oct-92 15:18:45

SPE

LENS SPECIFICATION
ID EB-2X

OBJ. DIST.	INFINITE	FOCAL LENGTH	27426.9104
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	144.7178
MARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	152.0875
CHIEF RAY HEIGHT	-.4629	OVERALL LENGTH	1554.6150
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0408	EXIT PUPIL POS.	-10.8215
F/NUMBER	89.9833	GAUSSIAN IM. HT.	18.6470

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION -.261862E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM			
1	INFINITE	.00100	BK7	1.51987T	678.41	SCHOTT
2	INFINITE	650.00000	AIR			
3	-2394.73740	-877.23980	-AIR			
CONIC B	-.239474E+14					
AXES A	.239474E+09	CC	-.100000E+01			
4	-858.24060	1454.48740	AIR			
CONIC B	.470171E+03					
AXES A	-.635232E+03	CC	-.282538E+01			
5	718.39000	4.00000	SF8	1.69736T	358.07	SCHOTT
6	92.73000	6.60000	SSK4	1.62192T	598.46	SCHOTT
7	-128.08000	50.00000	AIR			
8	INFINITE	7.00000	BK7	1.51987T	678.41	SCHOTT
9	INFINITE	5.00000	AIR			
10	INFINITE	50.00000	CALCITE	1.66356T	529.15	UNUSUAL
11	INFINITE	5.00000	AIR			
12	INFINITE	6.00000	BK7	1.51987T	678.41	SCHOTT
13	INFINITE	5.00000	AIR			
14	INFINITE	7.00000	CRQZB	1.53483T	707.37	UNUSUAL
15	INFINITE	5.00000	AIR			
16	INFINITE	3.00000	BK7	1.51987T	678.41	SCHOTT
17	INFINITE	50.00000	AIR			
18A	INFINITE	.00000	-AIR			
19A	INFINITE	-16.50000	-AIR			
20	-210.75000	-5.00000	BAK4	-1.57269T	607.06	SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06	SCHOTT
22	515.63000	-57.94790	-AIR			
23	-120.15000	-5.21000	BK7	-1.51987T	678.41	SCHOTT
24	76.21000	-2.90000	SF5	-1.68067T	368.78	SCHOTT
25	201.90000	-58.03881	-AIR			
26	75.53100	-3.20000	SF5	-1.68067T	368.78	SCHOTT
27	24.40600	-1.50000	BK7	-1.51987T	678.41	SCHOTT
28	-30.28700	128.79671G	-AIR			
29	INFINITE	-152.84491	-AIR			
30	466.59525	-2.50000	F5	-1.60947T	428.07	SCHOTT
31	-26.40990	-23.51403	-AIR			
32	-228.73106	-7.64000	FK5	-1.49012T	736.70	SCHOTT

33	32.60421	.00000	-AIR			
34	INFINITE	-.00010	BK7	-1.51987T	678.41	SCHOTT
35	INFINITE	-48.00000	-AIR			
36	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58	UNUSUAL
37	INFINITE	-48.00000	-AIR			
38	INFINITE	-.00010	BK7	-1.51987T	678.41	SCHOTT
39	INFINITE	-25.00000	-AIR			
40A	INFINITE	.00000	AIR			
41A	INFINITE	12.50000	AIR			
42	INFINITE	300.00000	CALCITE	1.66356T	529.15	UNUSUAL
43	INFINITE	15.00000	AIR			
44	182.72000	2.00000	SF5	1.68067T	368.78	SCHOTT
45	44.88000	4.80000	SK11	1.56737T	650.90	SCHOTT
46	-64.04000	127.36551	AIR			
47	8.57632	5.00000	LF5	1.58687T	456.99	SCHOTT
48	6.46007	144.71778	AIR			
49	INFINITE	7.36976	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

TILTS AND DECENTERS ALPHA,BETA,GAMMA,AXIS
X-DECN,YDECN,ZDECN

18 TDC 70 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00
19 TDC 70 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00
29 COINCIDENT WITH SURFACE 22
40 TDC 50 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00
41 TDC 50 SURFACES
.450000E+02 .000000E+00 .000000E+00 .000000E+00
.000000E+00 .000000E+00 .000000E+00

SYNOPSYS AI>CAP

LEAR APERTURE RADII

(Y-COORDINATE ONLY)

1	152.863	
2	152.863	
3	152.403	
4	41.4149	
5	20.0000	USER-ENTERED CAO
6	20.0000	USER-ENTERED CAO
7	20.0000	USER-ENTERED CAO
8	9.38960	
9	12.5000	USER-ENTERED CAO
10	12.5000	USER-ENTERED CAO
11	12.5000	USER-ENTERED CAO
12	12.5000	USER-ENTERED CAO
13	12.5000	USER-ENTERED CAO
14	12.5000	USER-ENTERED CAO

```
    15      12.5000      USER-ENTERED CAO
    16      12.5000      USER-ENTERED CAO
    17      8.29200
    18      10.7157
    19      7.44950
    20      15.0000      USER-ENTERED CAO
    21      15.0000      USER-ENTERED CAO
    22      15.0000      USER-ENTERED CAO
    23      15.0000      USER-ENTERED CAO
    24      15.0000      USER-ENTERED CAO
    25      15.0000      USER-ENTERED CAO
    26      9.00000      USER-ENTERED CAO
    27      9.00000      USER-ENTERED CAO
    28      9.00000      USER-ENTERED CAO
    29      7.86916
    30      4.36324
    31      4.43761
    32      7.89571
    33      8.45455
    34      8.45431
    35      8.45431
    36      8.44387
    37      8.44246
    38      8.43202
    39      8.43202
    40      11.9196
    41      8.42659
    42      12.5000      USER-ENTERED CAO
    43      12.5000      USER-ENTERED CAO
    44      13.2500      USER-ENTERED CAO
    45      13.2500      USER-ENTERED CAO
    46      13.2500      USER-ENTERED CAO
    47      2.61316
    48      2.28724
    49      19.8836
SYNOPSYS AI>
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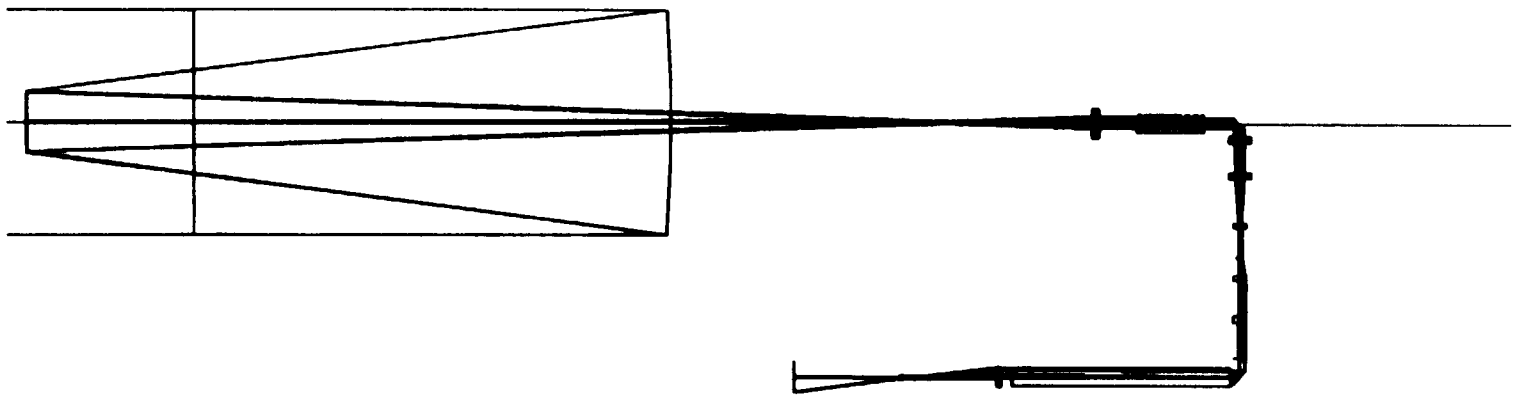


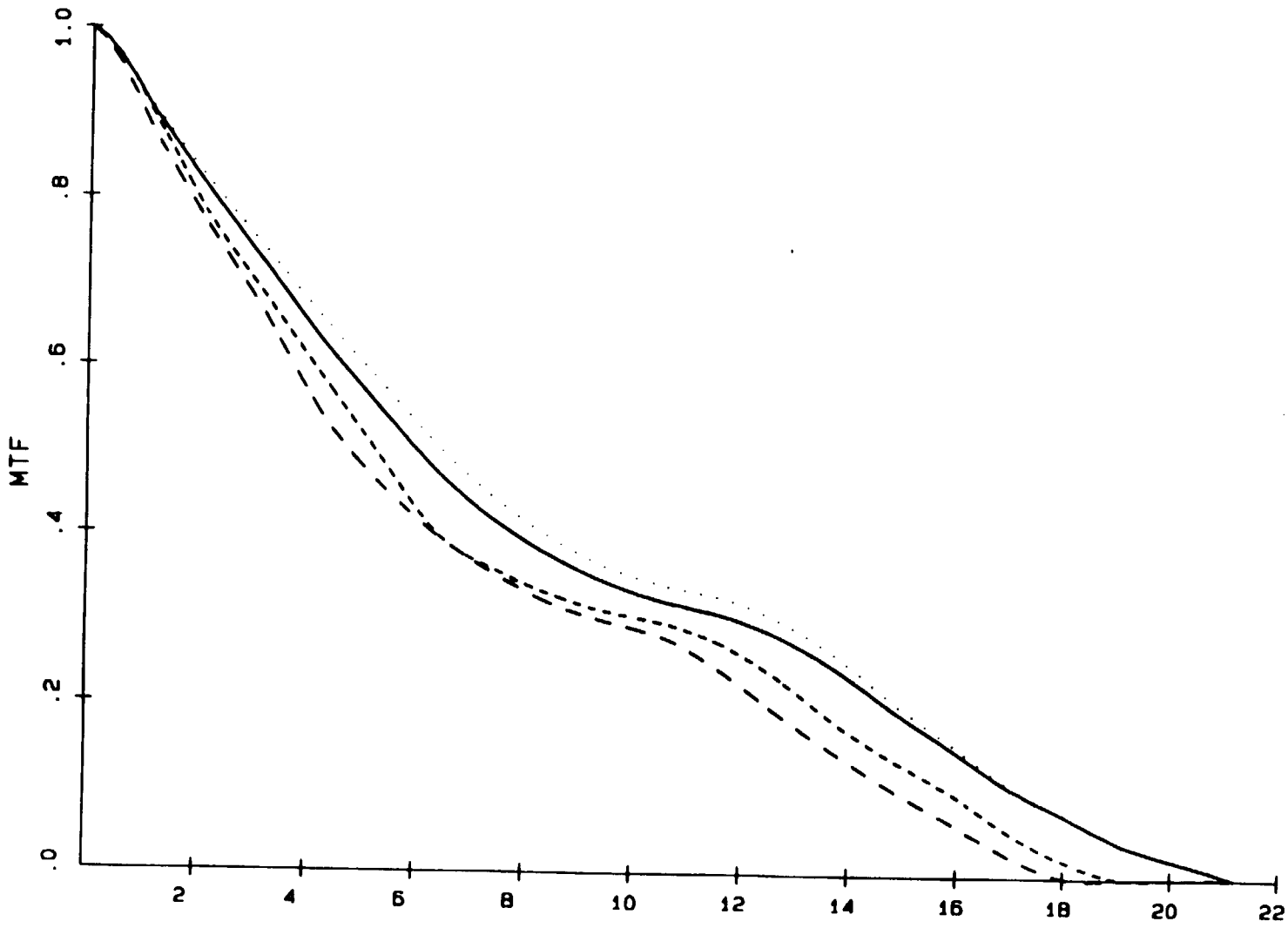
LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EB-2X

24-Jun-92 10:04:03

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .0000 FIELD 1.0000 FIELD
SAG.

WAVELENGTH	WEIGHT
.52502	1.000



ID EB-2X
1147
SEMI-FIELD = .0408 DEGREES SEMI-APERTURE = 152.4000 MM
DEFOCUS -7.369760

Tolerance for EB

```
GDS

PANT

CALL  PANT

CALL  PANT
VLIST TH 3 4      22 24 36 39 41
END
CALL  AANT
GNV 0 1 4 2

***      26 RAYS GENERATED IN COLOR      2 AT HBAR        .0000 GBAR        .0000
END
CALL  TOL .7464318E-02


TOLERANCE CALCULATIONS
CRITERION ON ABERRATIONS       .007464


VARIABLE LIST
NO.   SN  PAR                UPPER LIMIT      LOWER LIMIT        INCREMENT
 1    3   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 2    4   TH      .10000000E+05    .00000000E+00    .10000000E-02
 3   22   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 4   24   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 5   36   TH      .10000000E+05    .00000000E+00    .10000000E-02
 6   39   TH      .10000000E+05    .00000000E+00    .10000000E-02
 7   41   TH      .10000000E+05    .00000000E+00    .10000000E-02

SYSTEM ABERRATIONS
      1     .24310509E+00
      2     .19067327E+00
      3     .88583376E-01
      4     .19171393E-01
      5     .19171393E-01
      6     .88583376E-01
      7     .19067327E+00
      8     .24310509E+00
      9     .23121754E+00
     10     .22218920E+00
     11     .14594103E+00
     12     .88583376E-01
     13     .88583376E-01
     14     .14594103E+00
     15     .22218920E+00
     16     .23121754E+00
     17     .24310509E+00
     18     .22218920E+00
     19     .19067327E+00
     20     .19067327E+00
     21     .22218920E+00
     22     .24310509E+00
     23     .23121754E+00
     24     .24310509E+00
     25     .24310509E+00
     26     .23121754E+00
 1   TOTAL     .49762121E-02
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```
INITIAL MERIT FUNCTION    .247627E-04
  -.877239E+03     .310671E-04
  -.877236E+03     .597364E-04    1


TOLERANCE, PARAMETER NO.    1

 3  TH          -877.239800
 1      .772893E-02  *
EXTREME VALUE       -877.235636    TOLERANCE          -.004164

   .145449E+04     .243931E-04
   .145442E+04     .615536E-04    1
   .145442E+04     .607950E-04
   .145443E+04     .557831E-04    1


TOLERANCE, PARAMETER NO.    2

 4  TH          1454.487400
 1      .746881E-02  *
EXTREME VALUE       1454.428519    TOLERANCE           .058881

  -.152844E+03     .249279E-04
  -.152695E+03     .613971E-04    1


TOLERANCE, PARAMETER NO.    3

22  TH          -152.844910
 1      .783563E-02  *
EXTREME VALUE       -152.694737    TOLERANCE          -.150173

  -.235130E+02     .257989E-04
  -.234899E+02     .611261E-04    1


TOLERANCE, PARAMETER NO.    4

24  TH          -23.514027
 1      .781832E-02  *
EXTREME VALUE       -23.489881    TOLERANCE          -.024146

   .150010E+02     .245538E-04
   .148817E+02     .615050E-04    1
   .148827E+02     .610767E-04
   .148956E+02     .557861E-04    1


TOLERANCE, PARAMETER NO.    5

36  TH           15.000000
 1      .746901E-02  *
EXTREME VALUE        14.895552    TOLERANCE           .104448

   .127367E+03     .247043E-04
   .126942E+03     .615314E-04    1
   .126943E+03     .614113E-04
   .126991E+03     .557917E-04    1
```

TOLERANCE, PARAMETER NO. 6

39 TH 127.365510
 1 .746938E-02 *
EXTREME VALUE 126.991379 TOLERANCE .374131

.144719E+03	.247207E-04	
.144129E+03	.616315E-04	1
.144130E+03	.615446E-04	
.144199E+03	.557958E-04	1

TOLERANCE, PARAMETER NO. 7

41 TH 144.717780
 1 .746966E-02 *
EXTREME VALUE 144.198637 TOLERANCE .519143

TOLERANCE SUMMARY

VAR. NO.			VALUE	TOLERANCE	LIM. ABRN.
1	3	TH	-877.239800	-.004164	1
2	4	TH	1454.487400	.058881	1
3	22	TH	-152.844910	-.150173	1
4	24	TH	-23.514027	-.024146	1
5	36	TH	15.000000	.104448	1
6	39	TH	127.365510	.374131	1
7	41	TH	144.717780	.519143	1

SYNOPSYS AI>

APPENDIX E

BVM Design 30C
Correlation Tracker path
for 30 cm Telescope

PE

ENS SPECIFICATION
D EX1C

BJ. DIST.	INFINITE	FOCAL LENGTH	-7121.5302
BJ. HEIGHT	INFINITE	BACK FOCAL DIST.	176.8628
ARG. RAY HEIGHT	152.4000	PARAXIAL FOCAL P.	177.6424
IIEF RAY HEIGHT	-.9265	OVERALL LENGTH	1284.1106
ARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
IIEF RAY ANGLE	.0817	EXIT PUPIL POS.	-87.4971
/NUMBER	-23.3646	GAUSSIAN IM. HT.	-10.1213

VELENGTHS .65627 .52502 .63280
ITS MM
OP IS ON SURF. NO. 3
NS IS FOCAL. MAGNIFICATION .710059E-07
OBAL OPTION IS ON
OLARIZATION AND COATINGS ARE IGNORED.

RF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOTT
2	INFINITE	650.00000	AIR		
3	-2394.73740	-877.23980	-AIR		
CONIC B	-.239474E+14				
AXES A	.239474E+09	CC	-.100000E+01		
4	-858.24060	1453.64940	AIR		
CONIC B	.470171E+03				
AXES A	-.635232E+03	CC	-.282538E+01		
5	718.39000	4.00000	SF8	1.69736T	358.07 SCHOTT
6	92.73000	6.60000	SSK4	1.62192T	598.46 SCHOTT
7	-128.08000	50.00000	AIR		
8	INFINITE	7.00000	BK7	1.51987T	678.41 SCHOTT
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CROZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	50.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-16.50000	-AIR		
20	-210.75000	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63000	-120.00000	-AIR		
23A	INFINITE	.00000	AIR		
24A	INFINITE	176.86275	AIR		
25	INFINITE	.77966	AIR		

E: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

ORMATION COEFFICIENTS

NS AND DECENTERS ALPHA,BETA,GAMMA,AXIS
DCN,YDCN,ZDCN

```
   18      TDC    70  SURFACES
    .450000E+02      .000000E+00     .000000E+00     .000000E+00
    .000000E+00      .000000E+00     .000000E+00
   19      TDC    70  SURFACES
    .450000E+02      .000000E+00     .000000E+00     .000000E+00
    .000000E+00      .000000E+00     .000000E+00
   23      TDC    10  SURFACES
    .450000E+02      .000000E+00     .000000E+00     .000000E+00
    .000000E+00      .000000E+00     .000000E+00
   24      TDC    10  SURFACES
    .450000E+02      .000000E+00     .000000E+00     .000000E+00
    .000000E+00      .000000E+00     .000000E+00
SYNOPSYS AI>
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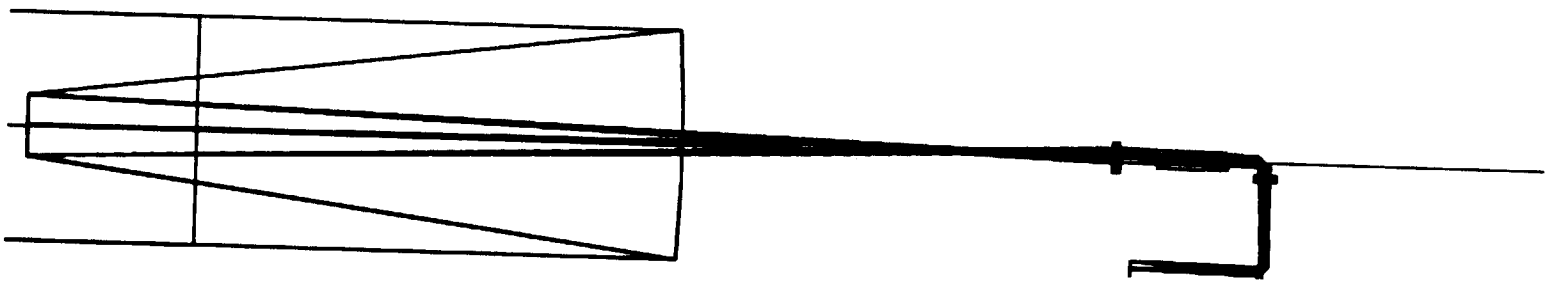
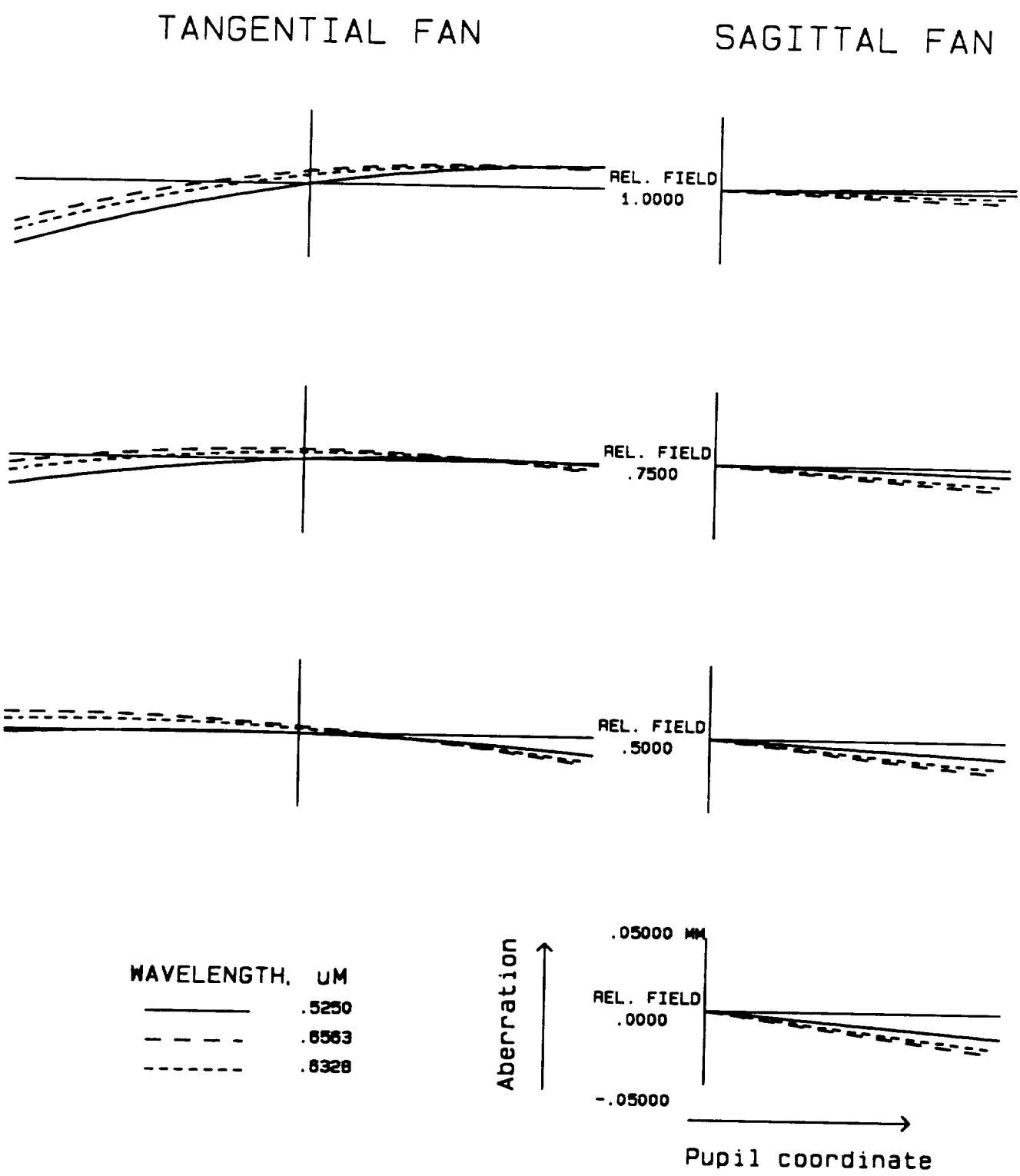


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EX1C

6-Oct-92 12:52:49

TRANSVERSE ABERRATION

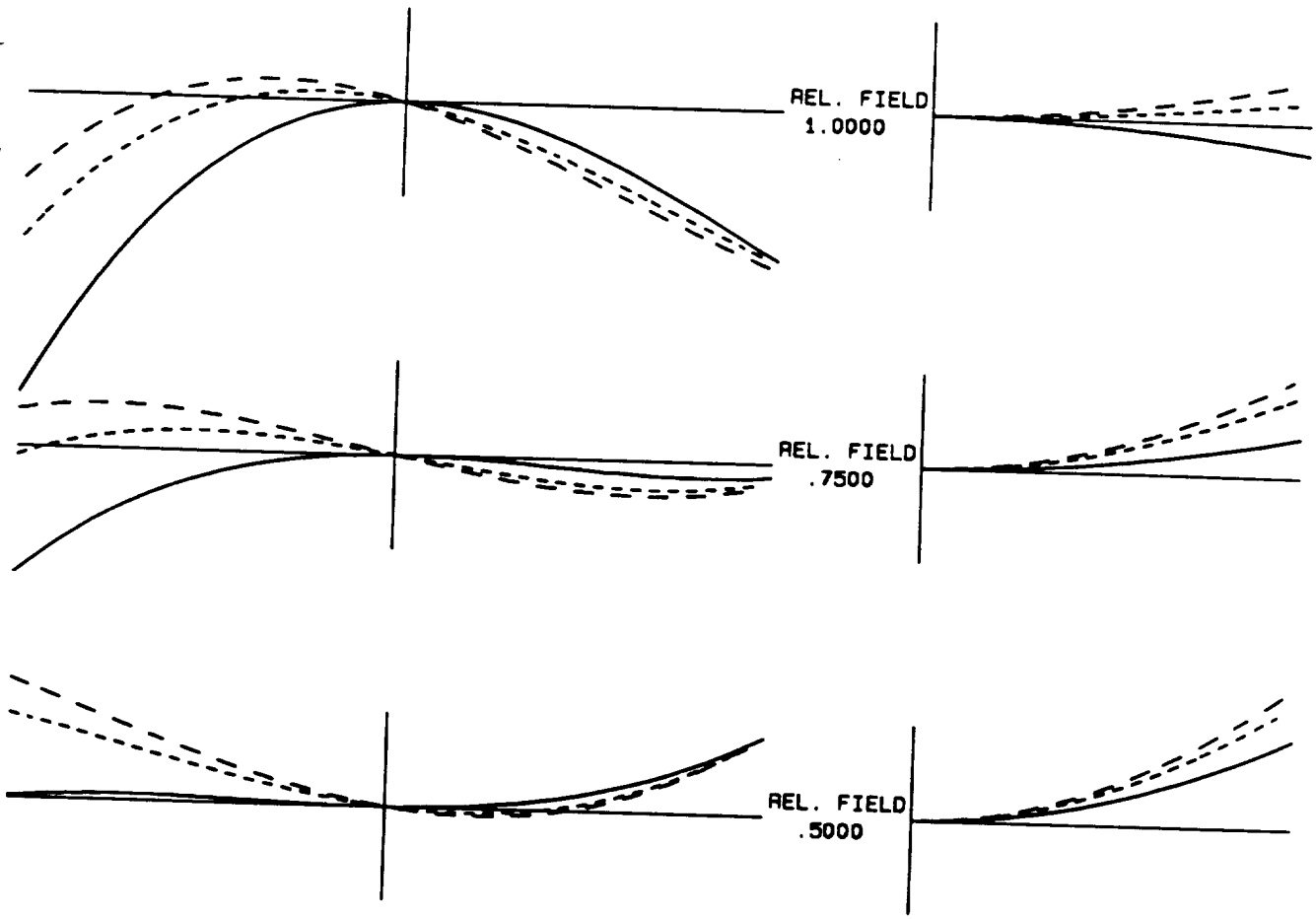


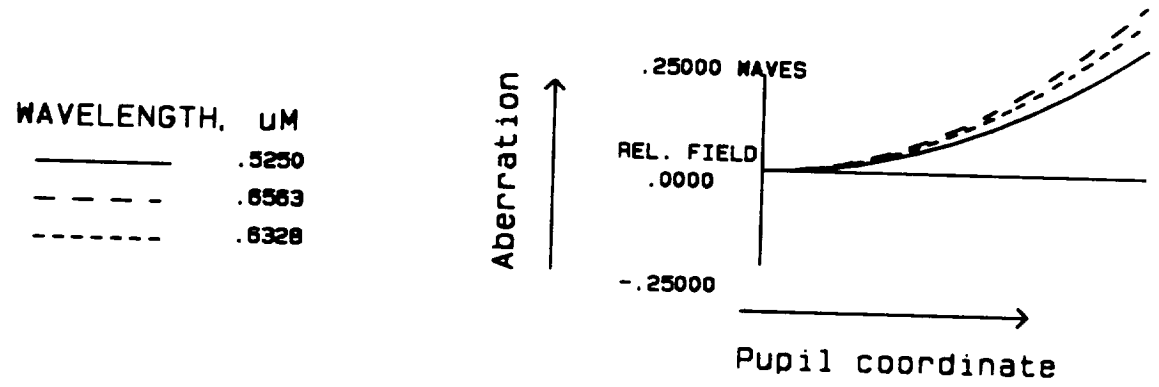
ID EX1C

1147

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 6-Oct-92 12:55:19

OPTICAL PATH DIFFERENCE

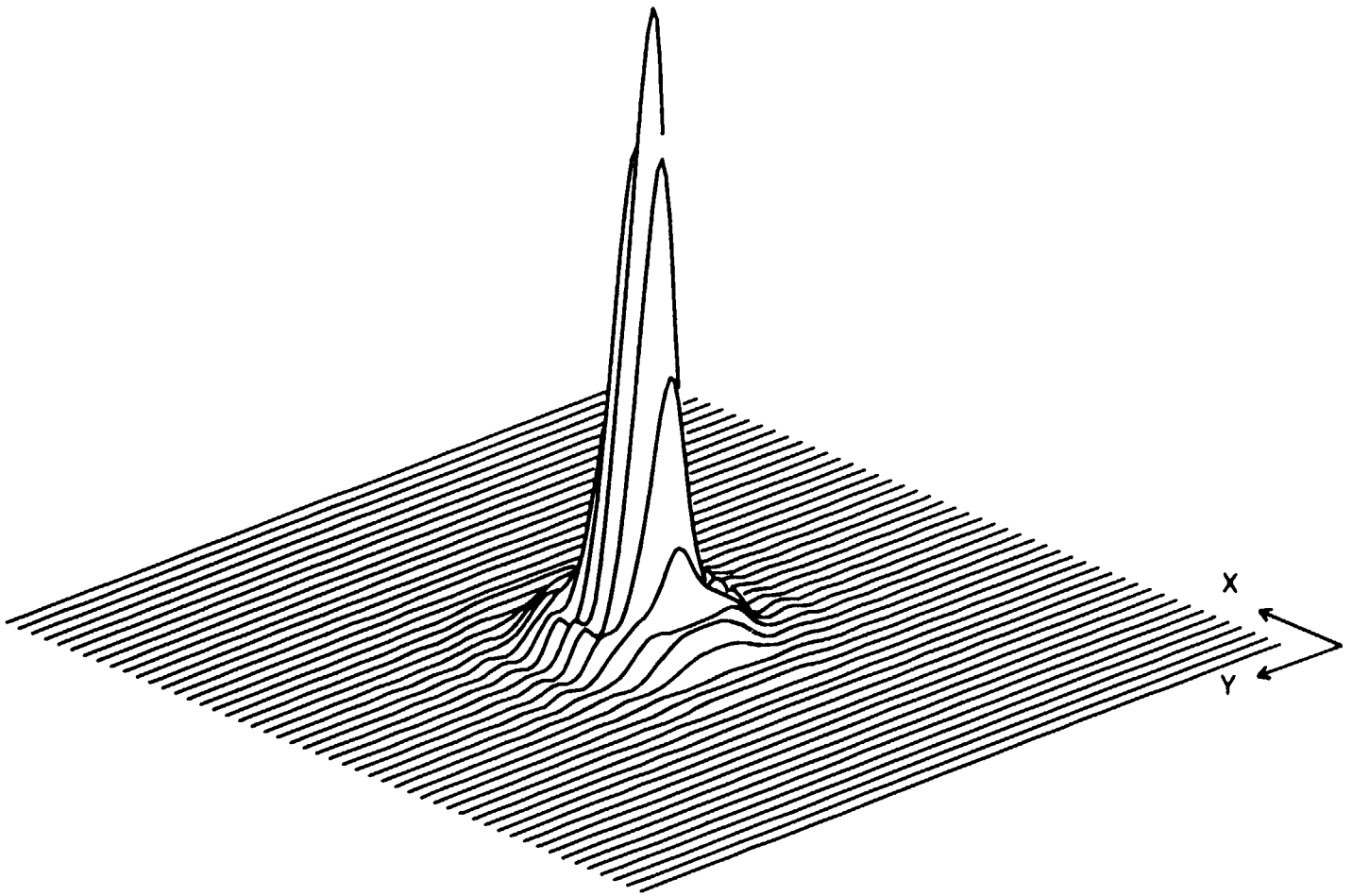




ID EX1C

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM 6-Oct-92 12:54:25

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .014962 MM ID EX1C

PSPRD 2 0. 300 0 0. WAVELENGTH .52502

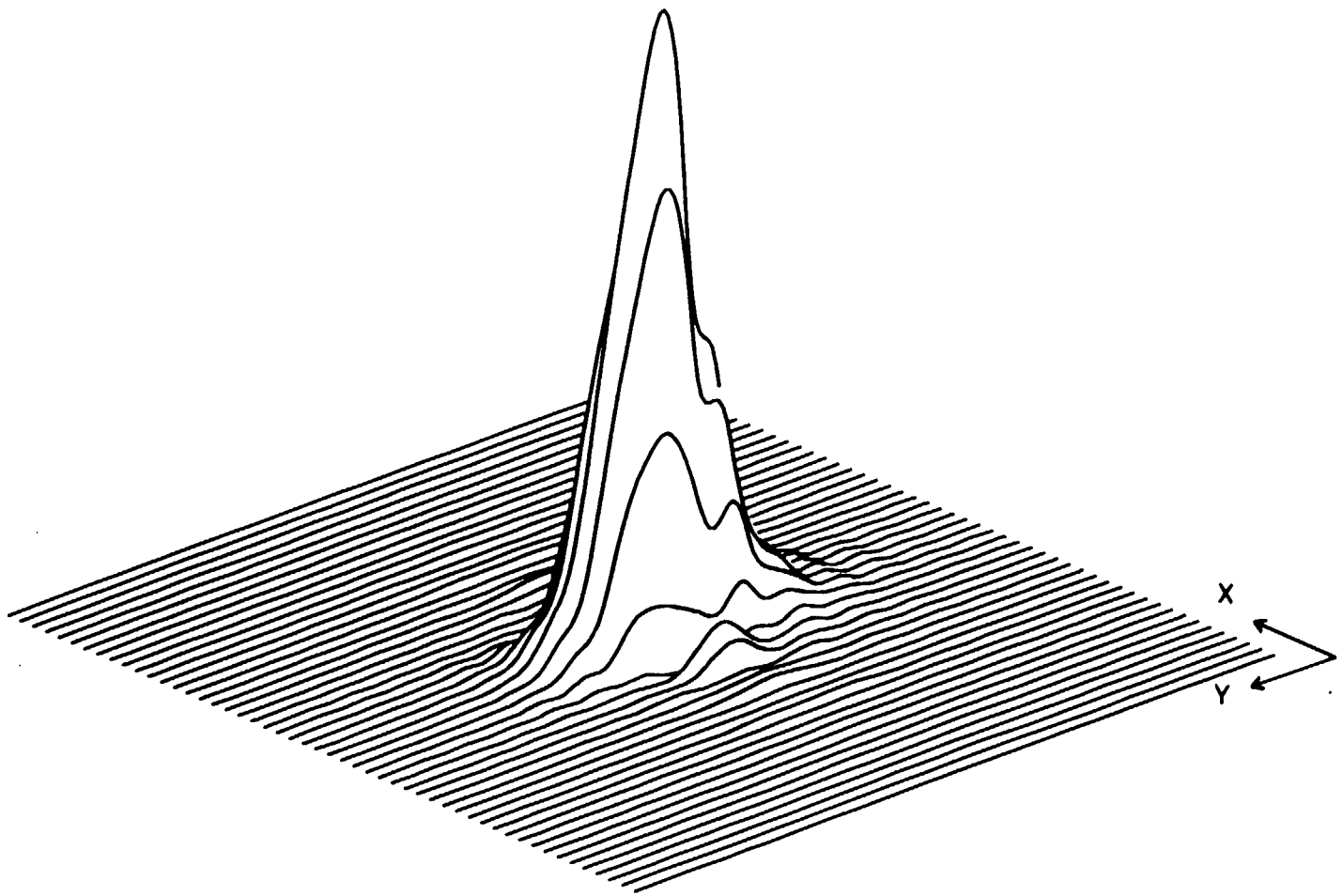
FRACTIONAL FIELD .0000 .0000

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

1147

6-Oct-92 12:50:40

DIFFRACTION INTENSITY PATTERN



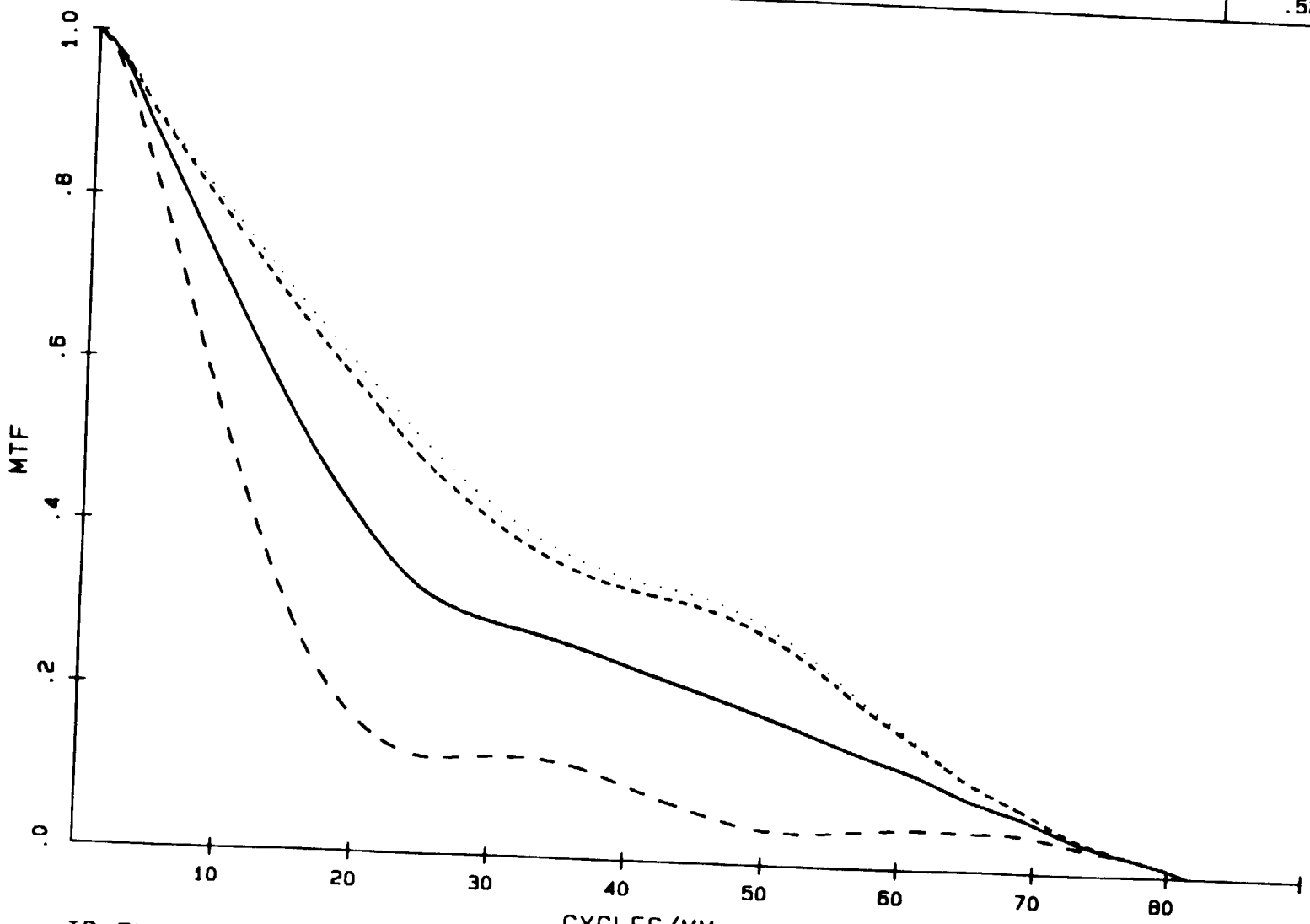
AIRY DISK RADIUS .014963 MM ID EX1C
PSPRD 2 1. 300 0 0. WAVELENGTH .52502 1147
FRACTIONAL FIELD 1.0000 .0000
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

6-Oct-92 12:51:42

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .0000 FIELD
SAG. 1.0000 FIELD

WAVELENGTH	WEIGHT
.52502	1.000



ID EX1C
SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

DEFOCUS -.779665

22-Oct-92 15:20:55

APPENDIX F

BVM Design 60F with 60 cm Telescope & Fabry-Perot Filter

SPE

LENS SPECIFICATION
ID EXBVMF1

OBJ. DIST.	INFINITE	FOCAL LENGTH	13900.5744
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	197.9454
MARG. RAY HEIGHT	304.8000	PARAXIAL FOCAL P.	198.0929
CHIEF RAY HEIGHT	-.4189	OVERALL LENGTH	2852.9115
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	300.0000
CHIEF RAY ANGLE	.0800	EXIT PUPIL POS.	-2.1203
F/NUMBER	22.8028	GAUSSIAN IM. HT.	19.3946

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 2
LENS IS FOCAL, MAGNIFICATION -.138903E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	300.00000	AIR		
2	-2162.50820	-728.58410	-AIR		
CONIC B	-.338062E+05				
AXES A	.855022E+04	CC	-.936032E+00		
3	-864.73471	2102.56020	AIR		
CONIC B	.115815E+04				
AXES A	-.100075E+04	CC	-.174665E+01		
4	229.10424	3.00000	BASF2	1.67153T	407.08 SCHOTT
5	55.82163	1.00000	AIR		
6	57.03947	8.00000	SK6	1.61790T	611.10 SCHOTT
7	-188.79066	175.00000	AIR		
8	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	25.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-25.00000	-AIR		
20	-210.75002	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63402	-204.27521	-AIR		
23	103.57000	-2.50000	BK7	-1.51987T	678.41 SCHOTT
24	-103.57000	-60.00000	-AIR		
25	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSUAL
26	INFINITE	-100.00000	-AIR		
27A	INFINITE	.00000	AIR		
28A	INFINITE	196.66989	AIR		
29	-881.32025	15.00000	BK7	1.51987T	678.41 SCHOTT
30	-190.13348	270.69343	AIR		
31	INFINITE	4.00000	FUSILICA	1.46104T	712.58 UNUSUAL
32	INFINITE	12.00000	AIR		

33	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
34	INFINITE	.00028	AIR			
35	INFINITE	18.00000	FUSILICA	1.46104T	712.58	UNUSUAL
36	INFINITE	.00000	AIR			
37	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
38	INFINITE	12.00000	AIR			
39	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
40	INFINITE	20.00000	AIR			
41	124.22334	10.00000	SF58	1.93387T	256.49	SCHOTT
42	104.24515	25.00000	AIR			
43	-395.45417	20.00000	FK5	1.49012T	736.70	SCHOTT
44	-125.41362	628.74704	AIR			
45	106.07000	4.10000	SSK4	1.62192T	598.46	SCHOTT
46	-72.69000	2.40000	SF8	1.69736T	358.07	SCHOTT
47	-484.14000	197.94538	AIR			
48	INFINITE	.14751	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

2	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.13505E-16	.00000E+00	.00000E+00	.00000E+00	-.10534E-21
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.32467E-27	.00000E+00			
3	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.11120E-13	.00000E+00	.00000E+00	.00000E+00	-.82312E-18
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.23829E-22	.00000E+00			

TILTS AND DECENTERS
X-DECN,YDECN,ZDECN ALPHA,BETA,GAMMA,AXIS

18 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
19 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
27 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
28 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		

SYNOPSYS AI>CAP

CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

1	305.219	
2	304.830	
3	100.801	
4	20.0000	USER-ENTERED CAO
5	18.7985	
6	20.0000	USER-ENTERED CAO

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        7       20.0000       USER-ENTERED CAO
        8       12.5000       USER-ENTERED CAO
        9       12.5000       USER-ENTERED CAO
       10       12.5000       USER-ENTERED CAO
       11       12.5000       USER-ENTERED CAO
       12       12.5000       USER-ENTERED CAO
       13       12.5000       USER-ENTERED CAO
       14       12.5000       USER-ENTERED CAO
       15       12.5000       USER-ENTERED CAO
       16       12.5000       USER-ENTERED CAO
       17       12.5000       USER-ENTERED CAO
       18       18.2850
       19       12.3884
       20       15.0000       USER-ENTERED CAO
       21       15.0000       USER-ENTERED CAO
       22       15.0000       USER-ENTERED CAO
       23       17.1500       USER-ENTERED CAO
       24       17.1500       USER-ENTERED CAO
       25       23.0000       USER-ENTERED CAO
       26       23.0000       USER-ENTERED CAO
       27       55.8832
       28       34.4091
       29       59.5630
       30       60.3398
       31       59.0000       USER-ENTERED CAO
       32       59.0000       USER-ENTERED CAO
       33       59.0000       USER-ENTERED CAO
       34       59.0000       USER-ENTERED CAO
       35       59.0000       USER-ENTERED CAO
       36       59.0000       USER-ENTERED CAO
       37       59.0000       USER-ENTERED CAO
       38       59.0000       USER-ENTERED CAO
       39       59.0000       USER-ENTERED CAO
       40       59.0000       USER-ENTERED CAO
       41       58.6301
       42       55.8022
       43       56.2684
       44       57.4075
       45       15.0000       USER-ENTERED CAO
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       48       17.8178
SYNOPSYS AI>
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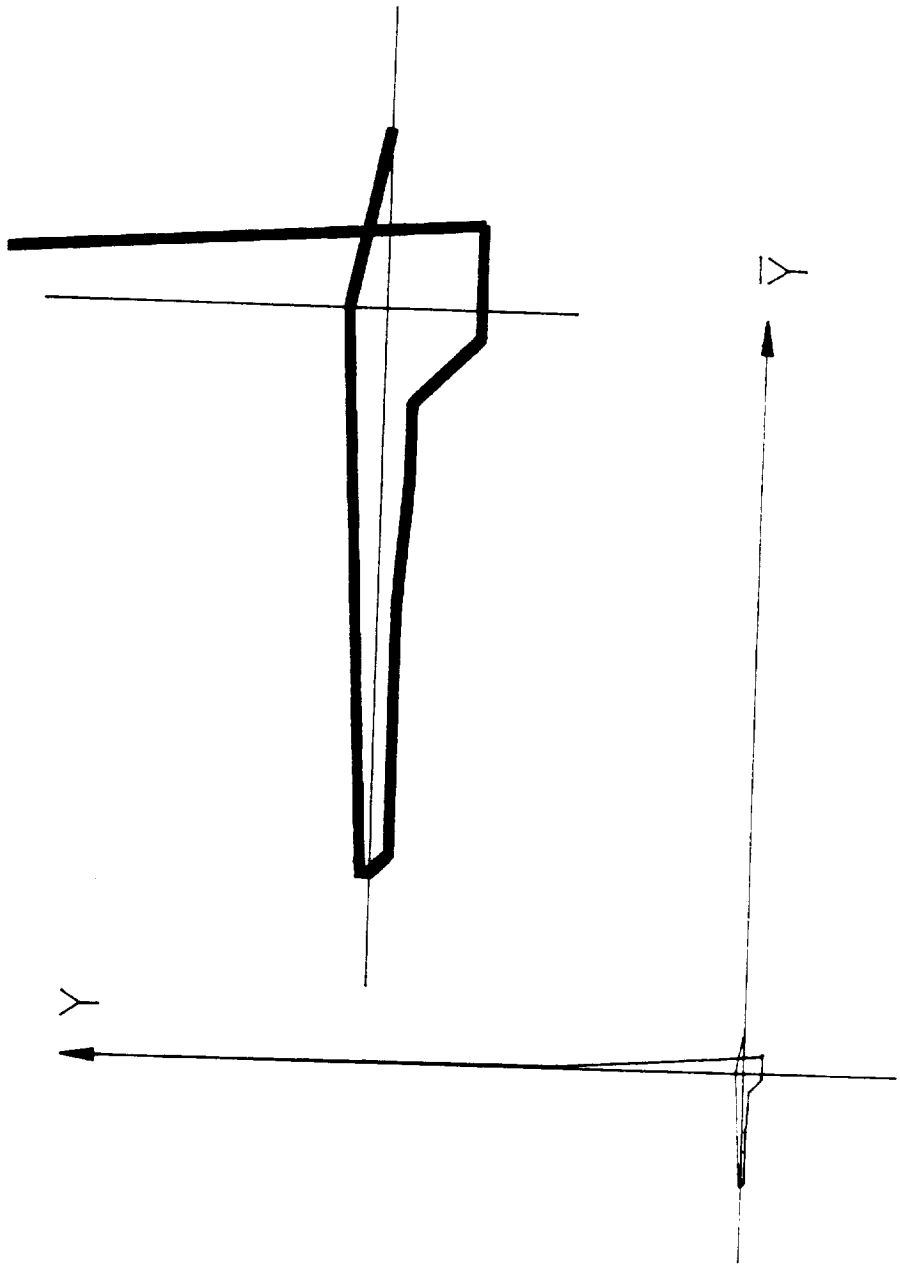
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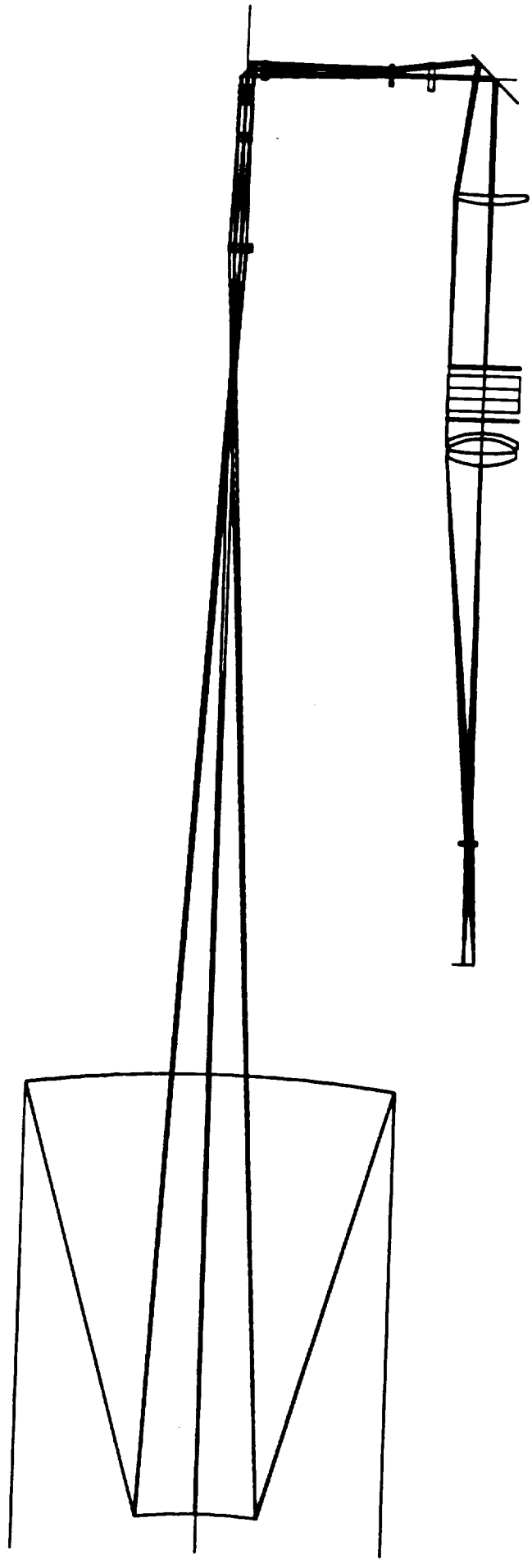
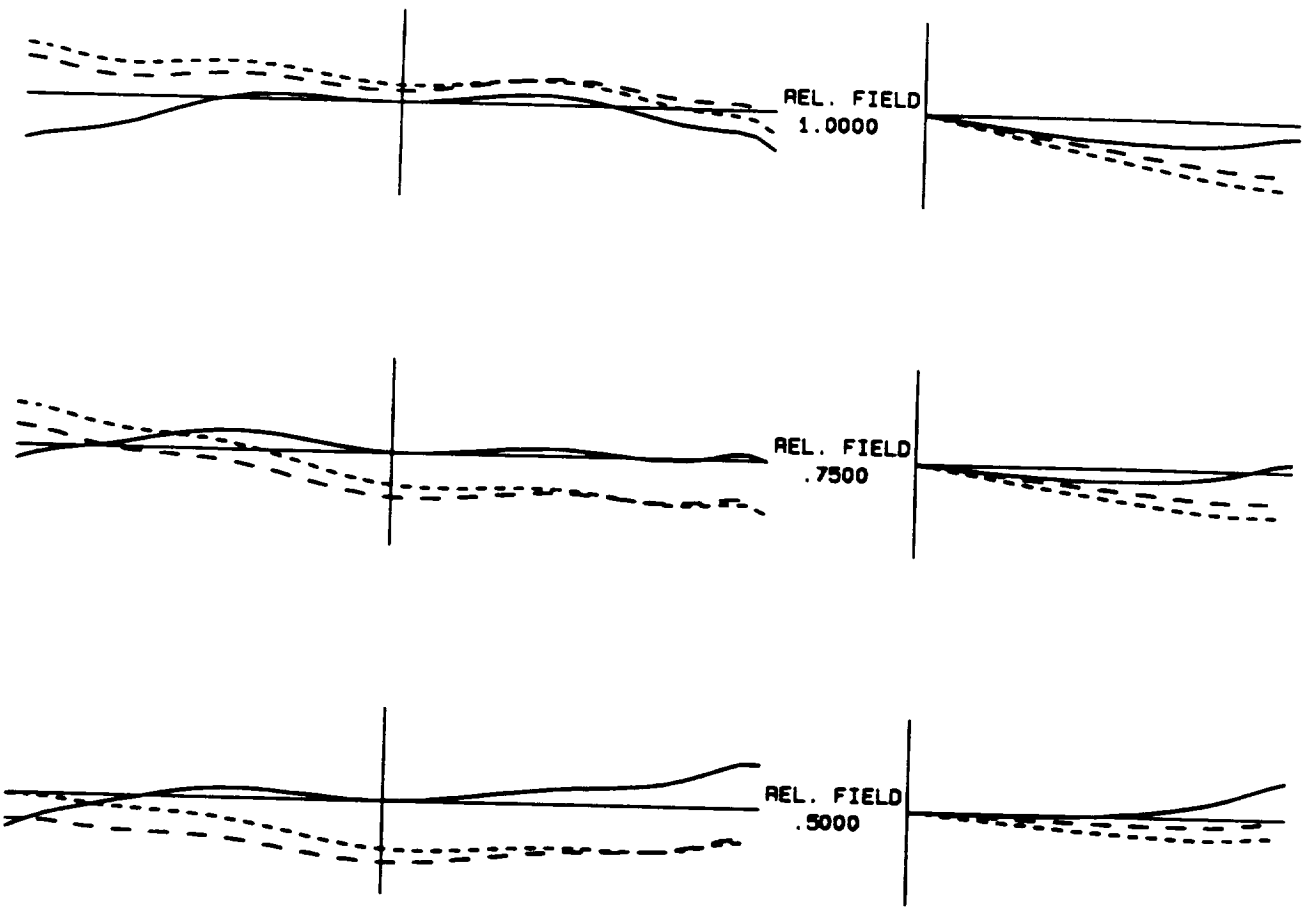
Y

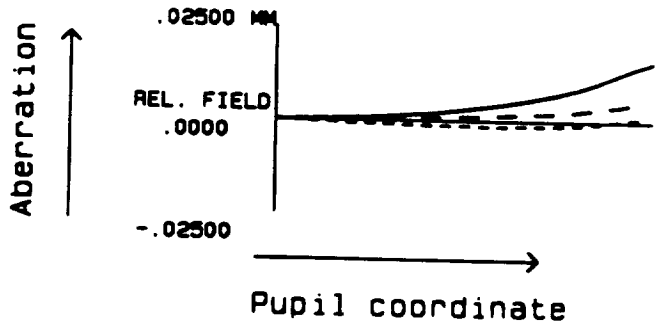


TRANSVERSE ABERRATION



WAVELENGTH, uM

———	.5250
– – – –	.6563
-------	.6328



ID EXBVMF1

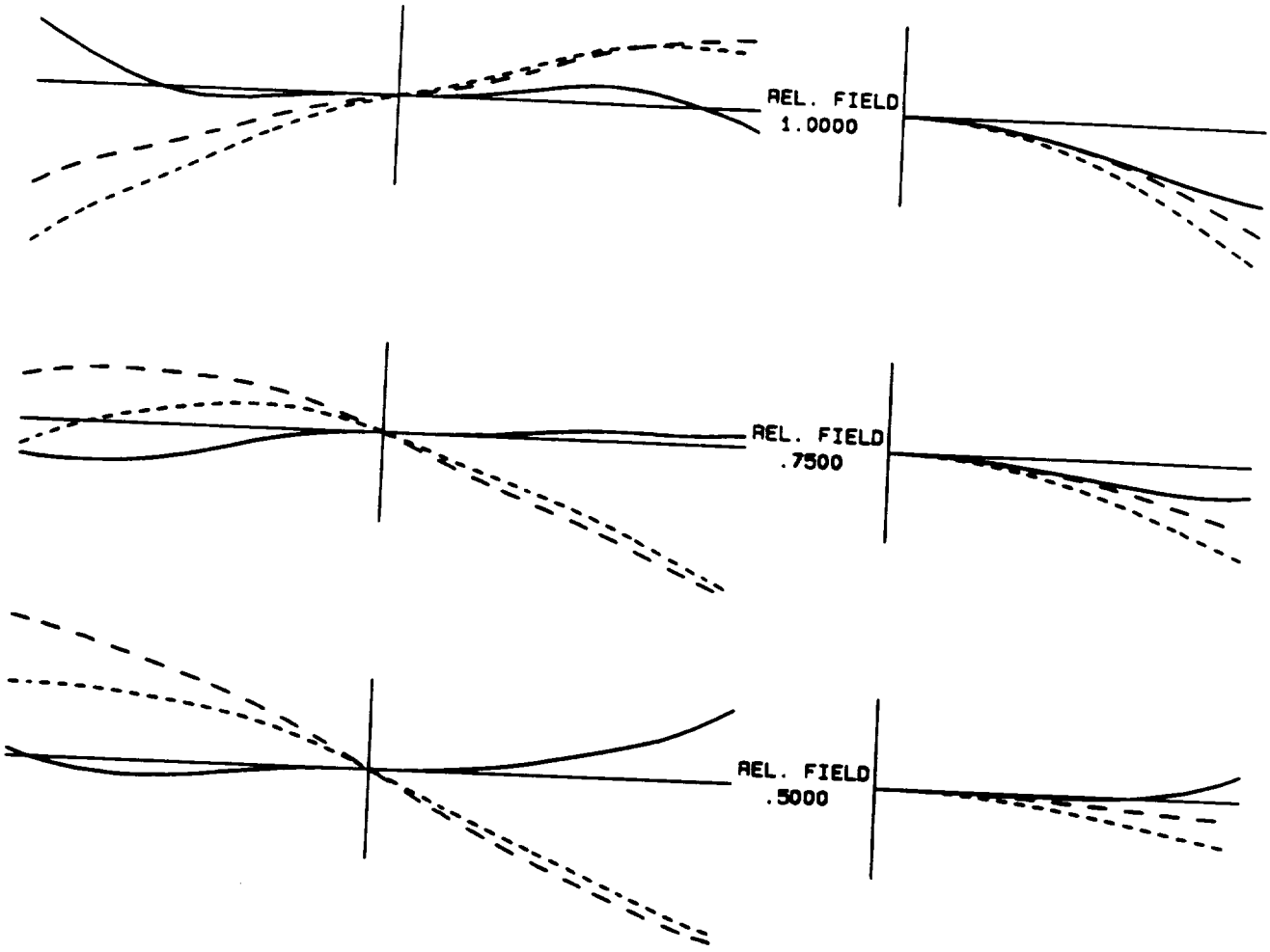
1147

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM 19-May-92 14:58:22

OPTICAL PATH DIFFERENCE

TANGENTIAL FAN

SAGITTAL FAN

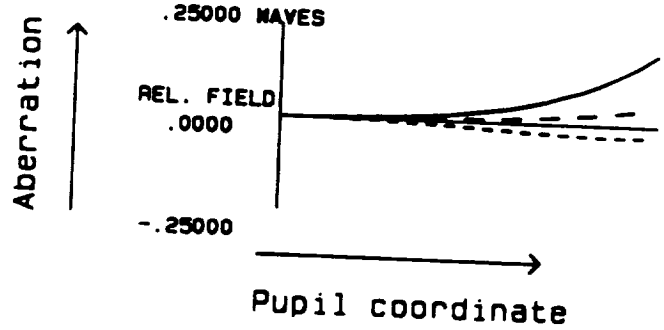


WAVELENGTH, uM

———— .5250

– – – – .6563

------- .6328

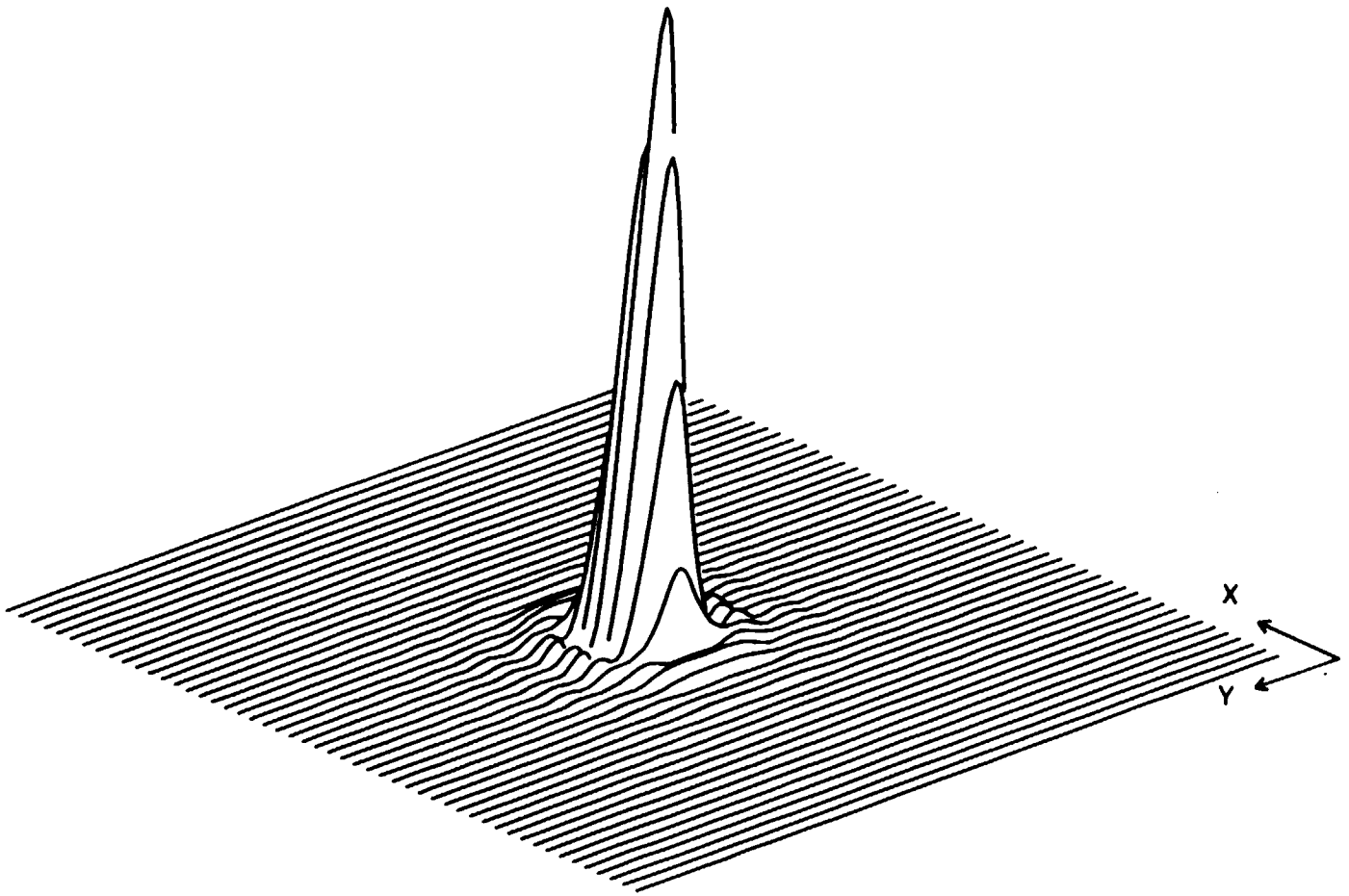


ID EXBVMF1

1147

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM 19-May-92 14:56:33

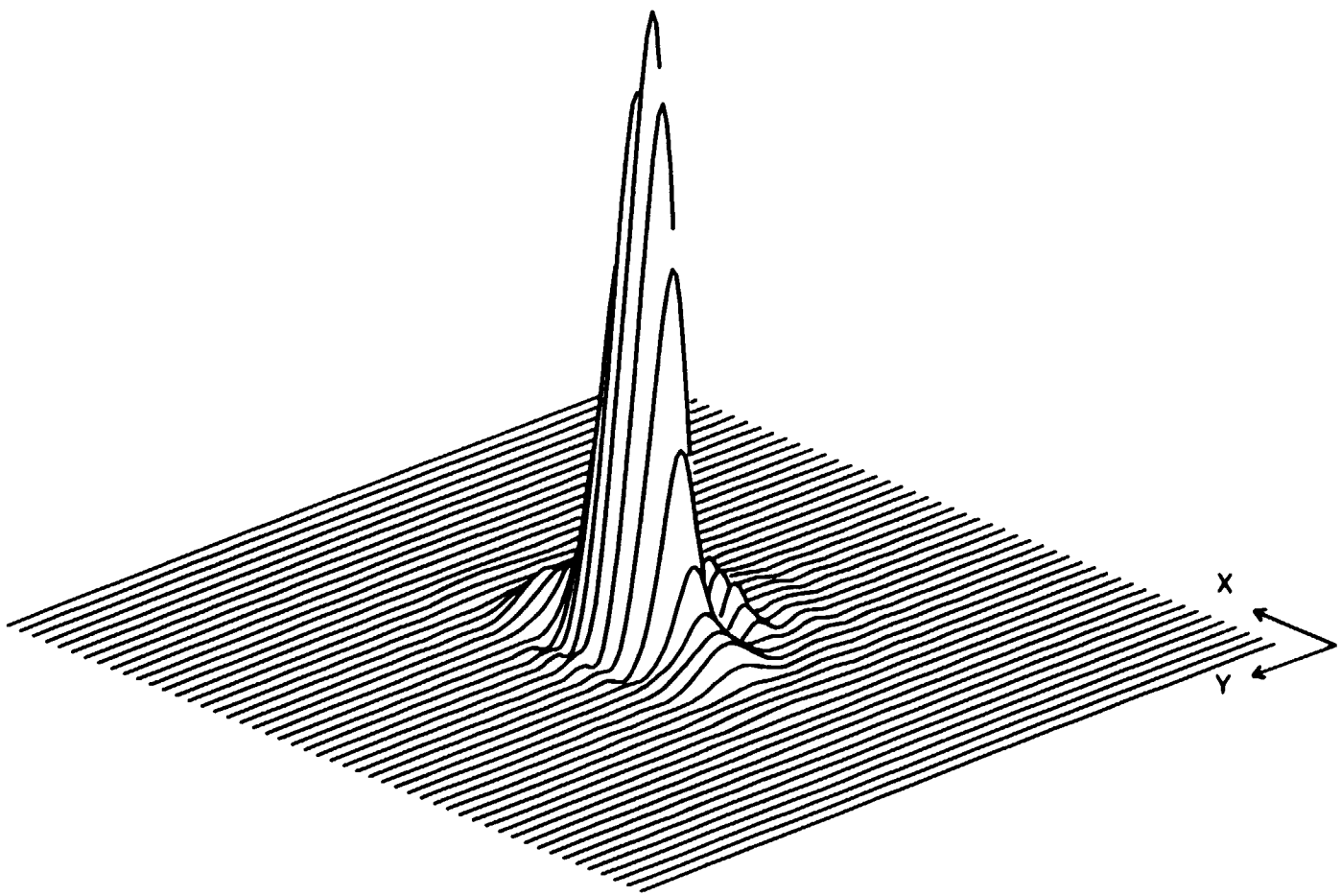
DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .014604 MM ID EXBVMF1
PSPRD 2 0. 300 0 0. WAVELENGTH .52502
FRACTIONAL FIELD .0000 .0000
SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

1147

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .010522 MM ID EXBVMF1

PSPRD 2 1. 300 0 0.WAVELENGTH .52502

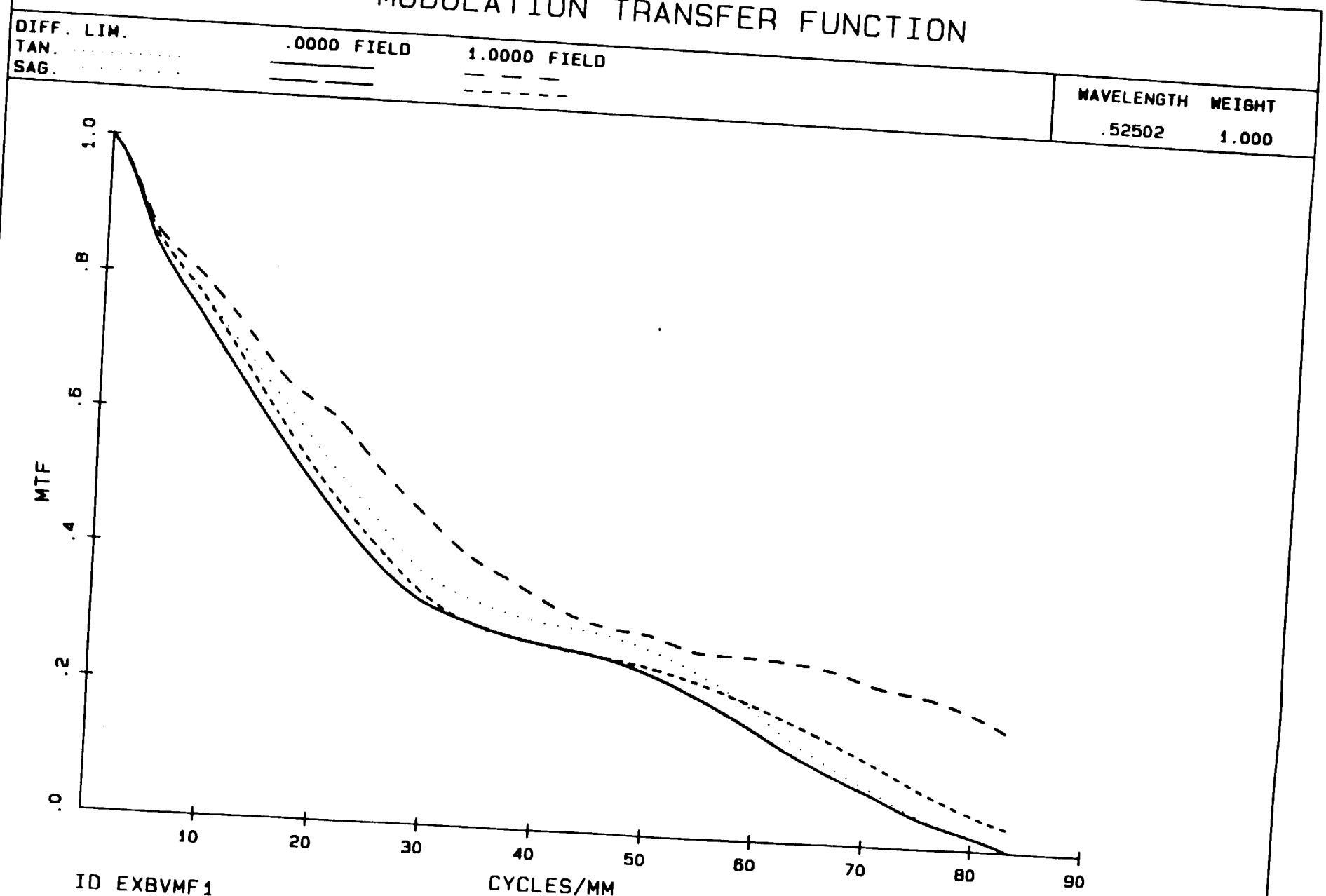
FRACTIONAL FIELD 1.0000 .0000

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

1147

19 May 02 14:59:28

MODULATION TRANSFER FUNCTION



ID EXBVMF1

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

1147

DEFOCUS -.147509

22-Oct-92 15:22:13

spe

LENS SPECIFICATION
ID EXBVMF2

OBJ. DIST.	INFINITE	FOCAL LENGTH	26138.6181
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	197.9454
MARG. RAY HEIGHT	304.8000	PARAXIAL FOCAL P.	199.2057
CHIEF RAY HEIGHT	-.2094	OVERALL LENGTH	2852.9115
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	300.0000
CHIEF RAY ANGLE	.0400	EXIT PUPIL POS.	28.5037
F/NUMBER	42.8783	GAUSSIAN IM. HT.	18.1135

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 2
LENS IS FOCAL, MAGNIFICATION -.259456E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	300.00000	AIR		
2	-2162.50820	-728.58410	-AIR		
CONIC B	-.338062E+05				
AXES A	.855022E+04	CC	-.936032E+00		
3	-864.73471	2102.56020	AIR		
CONIC B	.115815E+04				
AXES A	-.100075E+04	CC	-.174665E+01		
4	229.10424	3.00000	BASF2	1.67153T	407.08 SCHOTT
5	55.82163	1.00000	AIR		
6	57.03947	8.00000	SK6	1.61790T	611.10 SCHOTT
7	-188.79066	175.00000	AIR		
8	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	25.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-25.00000	-AIR		
20	-210.75002	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63402	-60.00000	-AIR		
23	-120.15000	-5.21000	BK7	-1.51987T	678.41 SCHOTT
24	76.21000	-2.90000	SF5	-1.68067T	368.78 SCHOTT
25	201.90000	-57.83696	-AIR		
26	75.53100	-3.20000	SF5	-1.68067T	368.78 SCHOTT
27	24.40600	-1.50000	BK7	-1.51987T	678.41 SCHOTT
28	-30.28700	130.64696G	-AIR		
29	INFINITE	-204.27521	-AIR		
30	103.57000	-2.50000	BK7	-1.51987T	678.41 SCHOTT
31	-103.57000	-60.00000	-AIR		
32	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSUAL

33	INFINITE	-100.00000	-AIR			
34A	INFINITE	.00000	AIR			
35A	INFINITE	196.66989	AIR			
36	-881.32025	15.00000	BK7	1.51987T	678.41	SCHOTT
37	-190.13348	270.69343	AIR			
38	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
39	INFINITE	12.00000	AIR			
40	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
41	INFINITE	.00028	AIR			
42	INFINITE	18.00000	FUSILICA	1.46104T	712.58	UNUSUAL
43	INFINITE	.00000	AIR			
44	INFINITE	21.00000	FUSILICA	1.46104T	712.58	UNUSUAL
45	INFINITE	12.00000	AIR			
46	INFINITE	4.00000	FUSILICA	1.46104T	712.58	UNUSUAL
47	INFINITE	20.00000	AIR			
48	124.22334	10.00000	SF58	1.93387T	256.49	SCHOTT
49	104.24515	25.00000	AIR			
50	-395.45417	20.00000	FK5	1.49012T	736.70	SCHOTT
51	-125.41362	628.74704	AIR			
52	106.07000	4.10000	SSK4	1.62192T	598.46	SCHOTT
53	-72.69000	2.40000	SF8	1.69736T	358.07	SCHOTT
54	-484.14001	197.94538	AIR			
55	INFINITE	1.26033	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

2	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.13505E-16	.00000E+00	.00000E+00	.00000E+00	-.10534E-21
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.32467E-27	.00000E+00			
3	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.11120E-13	.00000E+00	.00000E+00	.00000E+00	-.82312E-18
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.23829E-22	.00000E+00			

ILTS AND DECENTERS ALPHA,BETA,GAMMA,AXIS
-DECN,YDECN,ZDECN

18 TDC 50 SURFACES

.450000E+02	.000000E+00	.000000E+00	.000000E+00
.000000E+00	.000000E+00	.000000E+00	

19 TDC 50 SURFACES

.450000E+02	.000000E+00	.000000E+00	.000000E+00
.000000E+00	.000000E+00	.000000E+00	

29 COINCIDENT WITH SURFACE 22

34 TDC 50 SURFACES

.450000E+02	.000000E+00	.000000E+00	.000000E+00
.000000E+00	.000000E+00	.000000E+00	

35 TDC 50 SURFACES

.450000E+02	.000000E+00	.000000E+00	.000000E+00
.000000E+00	.000000E+00	.000000E+00	

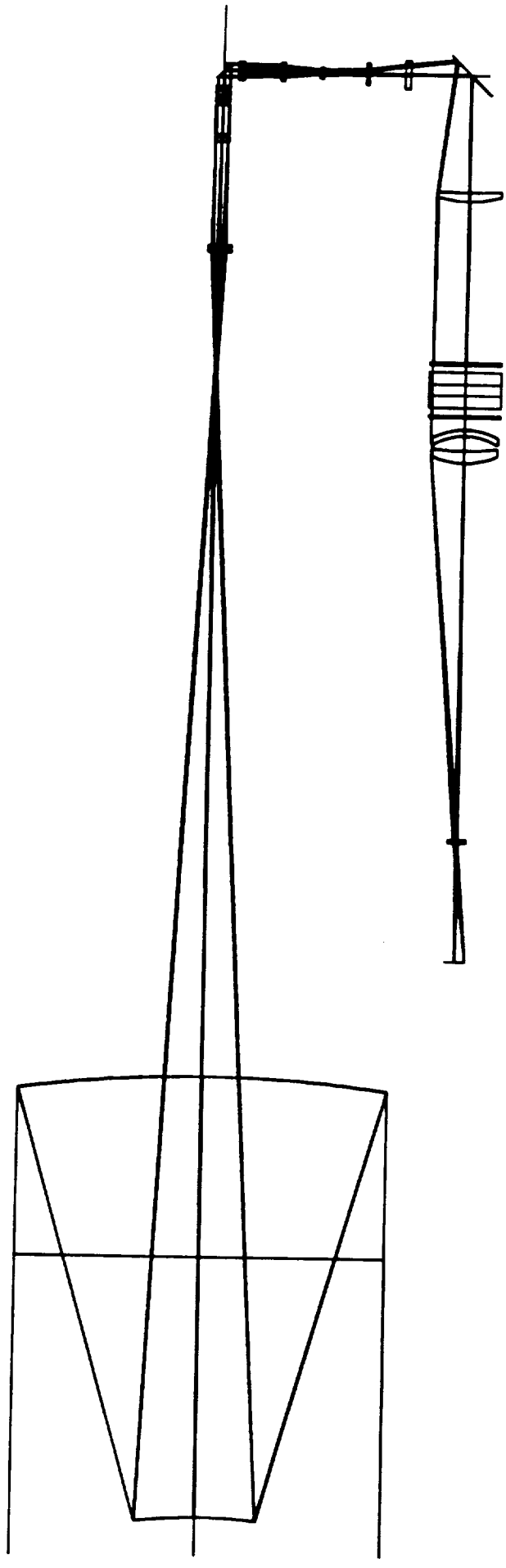
NOPSYS AI>cap

EAR APERTURE RADII

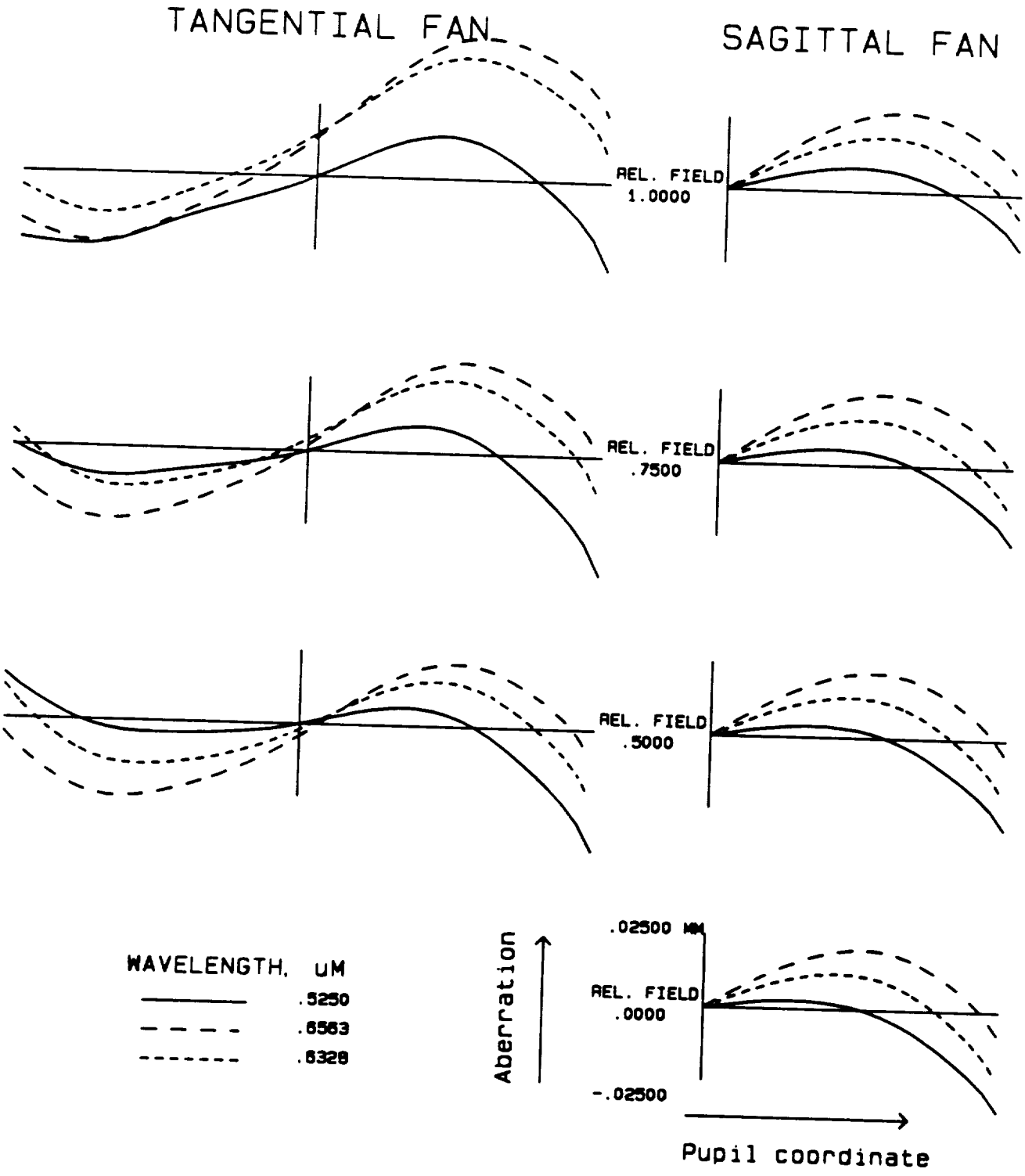
(Y-COORDINATE ONLY)

1	305.009	
2	304.815	
3	100.285	
4	20.0000	USER-ENTERED CAO
5	14.3490	
6	20.0000	USER-ENTERED CAO
7	20.0000	USER-ENTERED CAO
8	12.5000	USER-ENTERED CAO
9	12.5000	USER-ENTERED CAO
10	12.5000	USER-ENTERED CAO
11	12.5000	USER-ENTERED CAO
12	12.5000	USER-ENTERED CAO
13	12.5000	USER-ENTERED CAO
14	12.5000	USER-ENTERED CAO
15	12.5000	USER-ENTERED CAO
16	12.5000	USER-ENTERED CAO
17	12.5000	USER-ENTERED CAO
18	16.3087	
19	11.2906	
20	15.0000	USER-ENTERED CAO
21	15.0000	USER-ENTERED CAO
22	15.0000	USER-ENTERED CAO
23	15.0000	USER-ENTERED CAO
24	15.0000	USER-ENTERED CAO
25	15.0000	USER-ENTERED CAO
26	9.00000	USER-ENTERED CAO
27	9.00000	USER-ENTERED CAO
28	9.00000	USER-ENTERED CAO
29	9.72254	
30	17.1500	USER-ENTERED CAO
31	17.1500	USER-ENTERED CAO
32	23.0000	USER-ENTERED CAO
33	23.0000	USER-ENTERED CAO
34	46.6116	
35	28.9168	
36	52.8443	
37	53.7378	
38	59.0000	USER-ENTERED CAO
39	59.0000	USER-ENTERED CAO
40	59.0000	USER-ENTERED CAO
41	59.0000	USER-ENTERED CAO
42	59.0000	USER-ENTERED CAO
43	59.0000	USER-ENTERED CAO
44	59.0000	USER-ENTERED CAO
45	59.0000	USER-ENTERED CAO
46	59.0000	USER-ENTERED CAO
47	59.0000	USER-ENTERED CAO
48	55.3055	
49	52.7218	
50	53.3702	
51	54.5537	
52	15.0000	USER-ENTERED CAO
53	15.0000	USER-ENTERED CAO
54	15.0000	USER-ENTERED CAO
55	16.9053	

SYNOPSYS AI>



TRANSVERSE ABERRATION

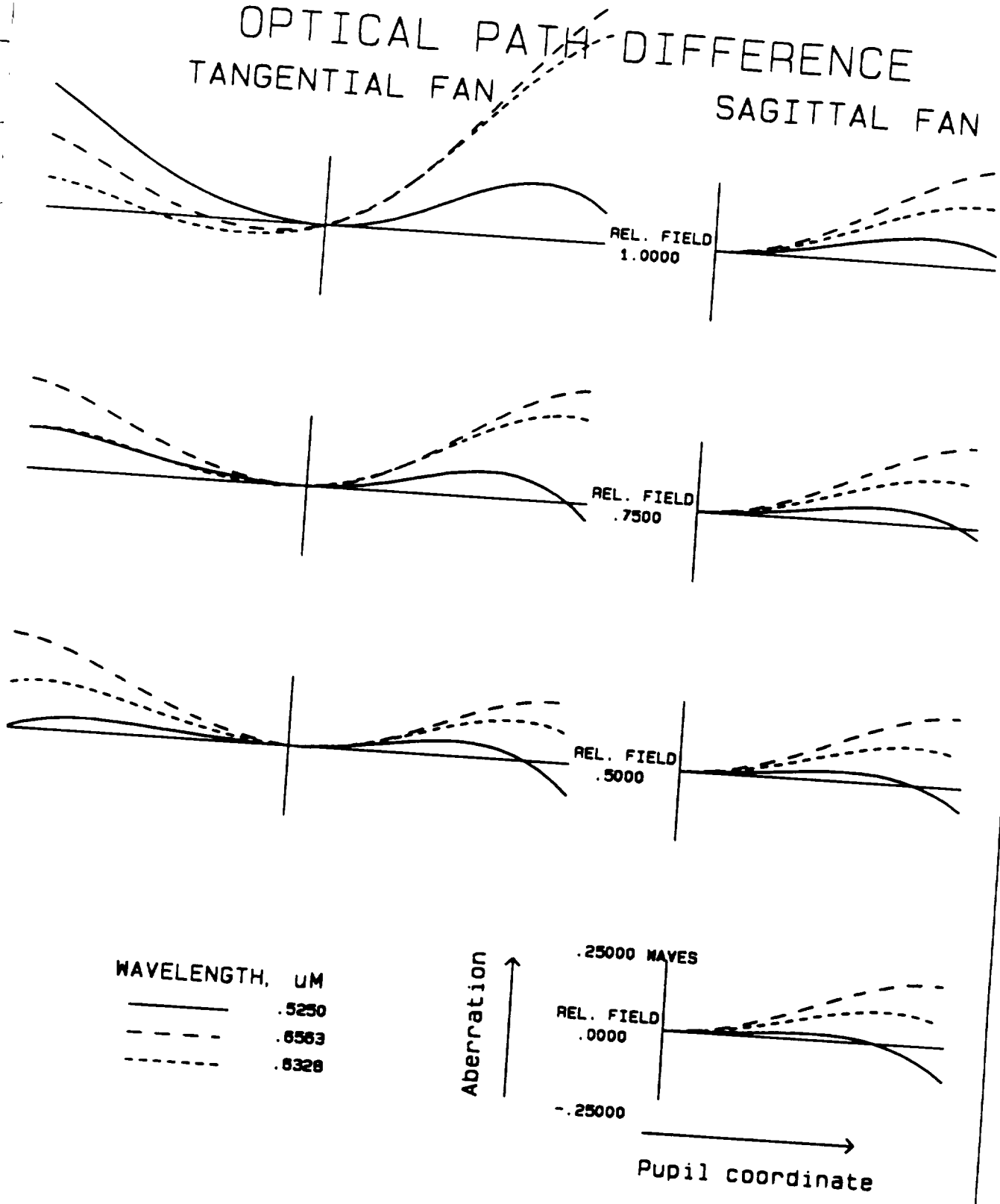


ID EXBVMF2

1147

SEMI-FIELD = .0400 DEGREES SEMI-APERTURE = 304.8000 MM 19-May-92 15: 10: 47

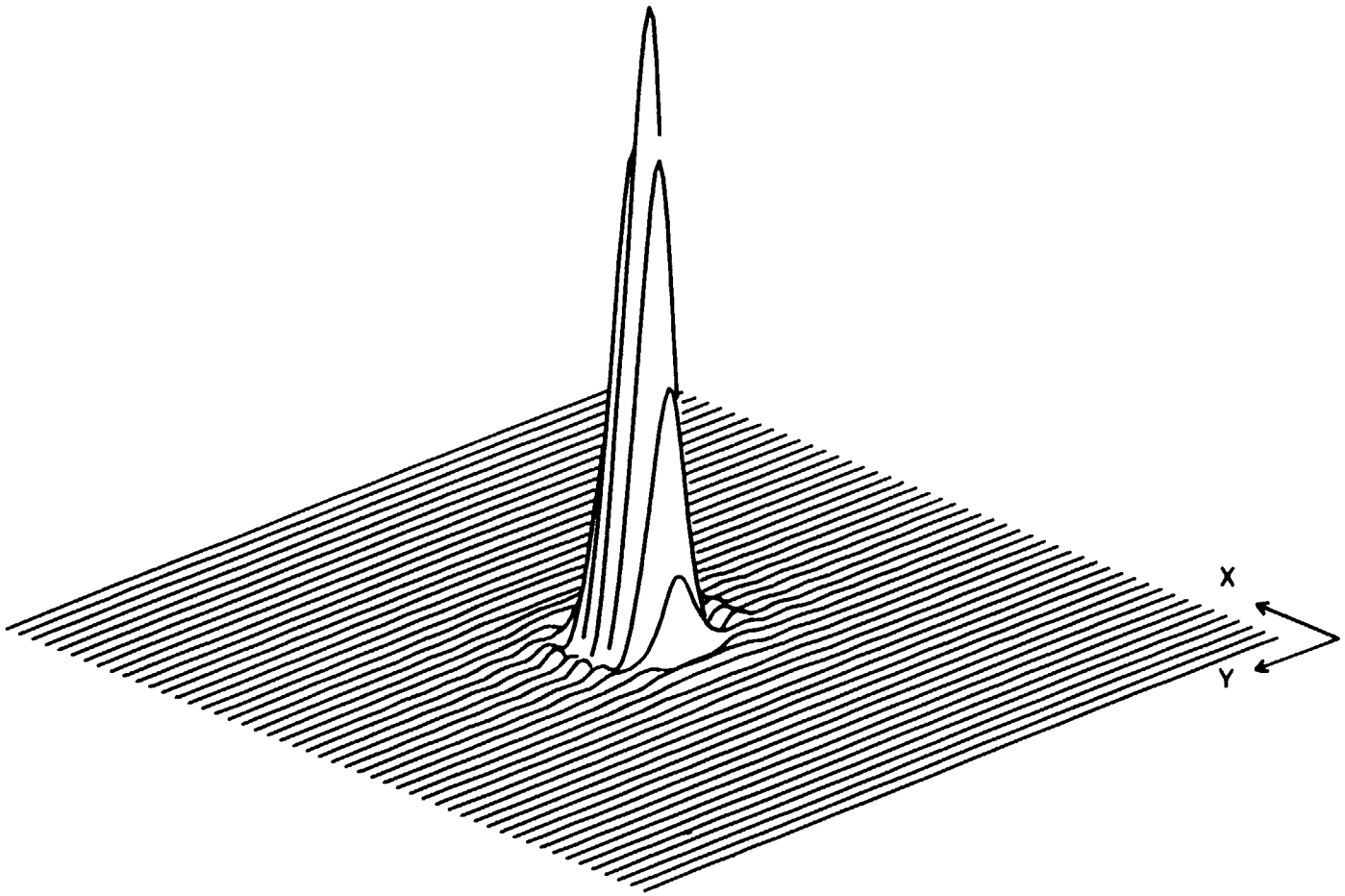
OPTICAL PATH DIFFERENCE



ID EXBVMF2

SEMI-FIELD = .0400 DEGREES SEMI-APERTURE = 304.8000 MM 19-May-92 15: 09: 46

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .027425 MM ID EXBVMF2

PSPRD 2 0. 300 0 0. WAVELENGTH .52502

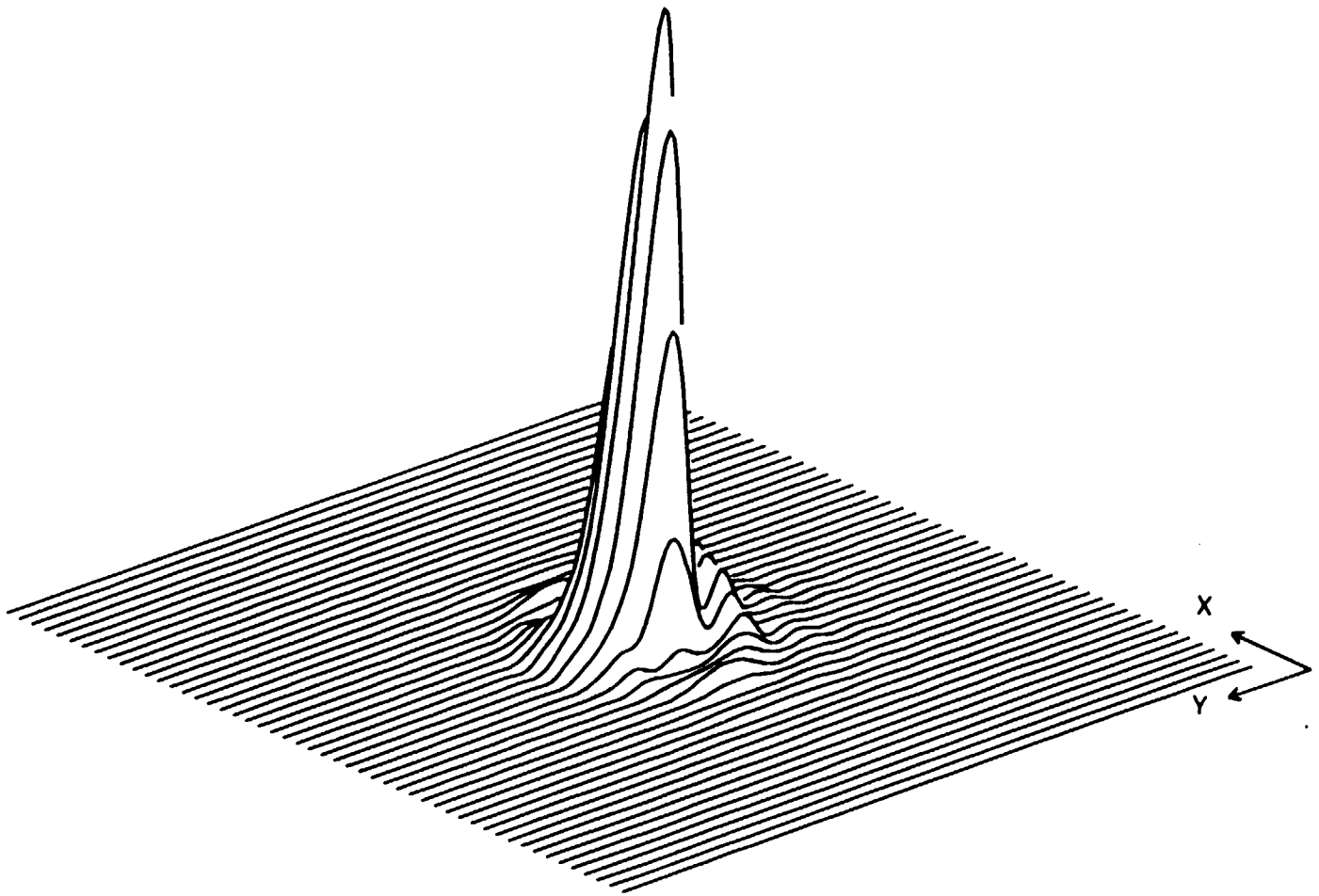
FRACTIONAL FIELD .0000 .0000

SEMI-FIELD = .0400 DEGREES SEMI-APERTURE = 304.8000 MM

1147

19-May-92 15:11:53

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .021370 MM ID EXBVMF2
PSPRD 2 1. 300 0 0. WAVELENGTH .52502 1147
FRACTIONAL FIELD 1.0000 .0000
SEMI-FIELD = .0400 DEGREES SEMI-APERTURE = 304.8000 MM

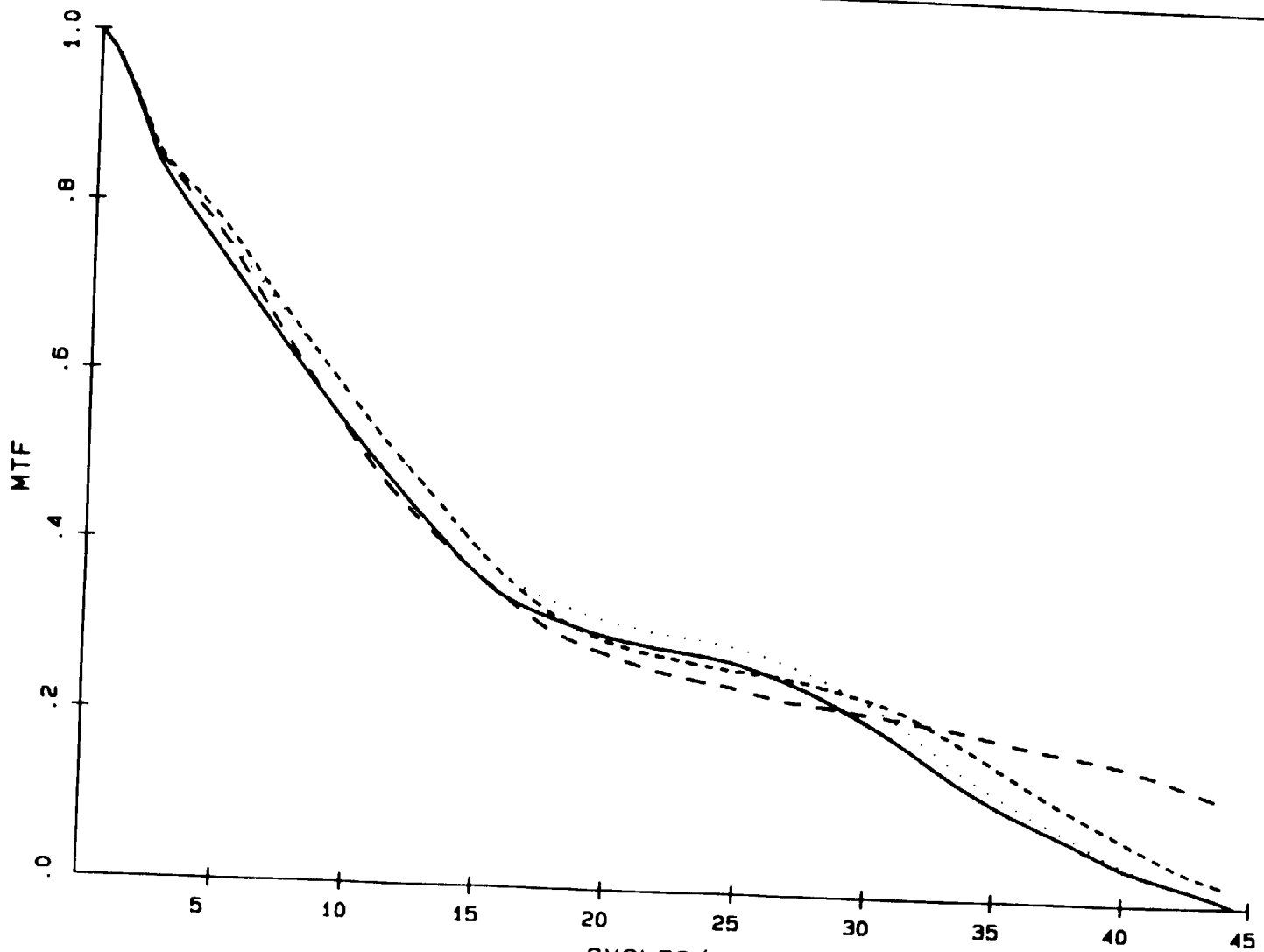
19-May-92 15:12:53

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .....
SAG. .....

.0000 FIELD
1.0000 FIELD

WAVELENGTH	WEIGHT
.52502	1.000



ID EXBVMF2

1147

SEMI-FIELD = .0400 DEGREES SEMI-APERTURE = 304.8000 MM DEFOCUS -1.260333

Tolerance for EXBVMF1

```
GDS

PANT

CALL  PANT

CALL  PANT
VLIST TH 2 3 5   22 28 30 42 44 47
END
CALL  AANT
GNV 0 1 4 2

***      26 RAYS GENERATED IN COLOR      2 AT HBAR        .0000 GBAR        .0000

END
CALL  TOL .45936E-02

TOLERANCE CALCULATIONS
CRITERION ON ABERRATIONS      .004594

VARIABLE LIST
NO.   SN  PAR                UPPER LIMIT      LOWER LIMIT        INCREMENT
 1    2   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 2    3   TH      .10000000E+05    .00000000E+00    .10000000E-02
 3    5   TH      .10000000E+05    .00000000E+00    .10000000E-02
 4   22   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 5   28   TH      .10000000E+05    .00000000E+00    .10000000E-02
 6   30   TH      .10000000E+05    .00000000E+00    .10000000E-02
 7   42   TH      .10000000E+05    .00000000E+00    .10000000E-02
 8   44   TH      .10000000E+05    .00000000E+00    .10000000E-02
 9   47   TH      .10000000E+05    .00000000E+00    .10000000E-02

SYSTEM ABERRATIONS
      1    .12498327E+00
      2    .45265217E-01
      3    .12568711E-01
      4    .21427030E-02
      5    .21427030E-02
      6    .12568711E-01
      7    .45265217E-01
      8    .12498327E+00
      9    .16165599E+00
     10    .67457005E-01
     11    .26902957E-01
     12    .12568711E-01
     13    .12568711E-01
     14    .26902957E-01
     15    .67457005E-01
     16    .16165599E+00
     17    .12498327E+00
     18    .67457005E-01
     19    .45265217E-01
     20    .45265217E-01
     21    .67457005E-01
     22    .12498327E+00
     23    .16165599E+00
     24    .12498327E+00
     25    .12498327E+00
```

```
      26     .16165599E+00
   1  TOTAL     .30624469E-02
 INITIAL MERIT FUNCTION    .937858E-05
   -.728583E+03     .340917E-04
   -.728584E+03     .200868E-04    1


 TOLERANCE, PARAMETER NO.    1

   2  TH          -728.584100
   1      .448183E-02  *
 EXTREME VALUE      -728.583549    TOLERANCE          -.000551

    .210256E+04     .889529E-05
    .210254E+04     .230661E-04    1


 TOLERANCE, PARAMETER NO.    2

   3  TH          2102.560200
   1      .480272E-02  *
 EXTREME VALUE      2102.541048    TOLERANCE           .019152

    .100100E+01     .603644E-05
    .997471E+00     .239862E-04    1
    .998471E+00     .169728E-04
    .997862E+00     .210269E-04    1


 TOLERANCE, PARAMETER NO.    3

   5  TH             1.000000
   1      .458551E-02  *
 EXTREME VALUE          .997862    TOLERANCE           .002138

   -.204274E+03     .959118E-05
   -.204231E+03     .228896E-04    1


 TOLERANCE, PARAMETER NO.    4

  22  TH          -204.275210
   1      .478430E-02  *
 EXTREME VALUE      -204.230849    TOLERANCE          -.044361

    .196671E+03     .937725E-05
    .189636E+03     .230410E-04    1


 TOLERANCE, PARAMETER NO.    5

  28  TH           196.669890
   1      .480011E-02  *
 EXTREME VALUE       189.635860    TOLERANCE          7.034030

    .270694E+03     .936912E-05
    .269703E+03     .229442E-04    1


 TOLERANCE, PARAMETER NO.    6
```

```
   30  TH              270.693430
    1       .479001E-02  *
   EXTREME VALUE        269.702548    TOLERANCE          .990882

      .250010E+02      .936666E-05
      .242133E+02      .229626E-04    1

 TOLERANCE, PARAMETER NO.    7

   42  TH              25.000000
    1       .479193E-02  *
   EXTREME VALUE        24.213303     TOLERANCE          .786697

      .628748E+03      .937268E-05
      .627159E+03      .229022E-04    1

 TOLERANCE, PARAMETER NO.    8

   44  TH              628.747040
    1       .478562E-02  *
   EXTREME VALUE        627.158561    TOLERANCE          1.588479

      .197946E+03      .929093E-05
      .197839E+03      .229728E-04    1

 TOLERANCE, PARAMETER NO.    9

   47  TH              197.945380
    1       .479300E-02  *
   EXTREME VALUE        197.838636    TOLERANCE          .106744

 TOLERANCE SUMMARY
 VAR. NO.                            VALUE          TOLERANCE  LIM. ABRN.

     1       2   TH                -728.584100      -.000551        1
     2       3   TH                2102.560200       .019152        1
     3       5   TH                   1.000000       .002138        1
     4      22   TH                -204.275210      -.044361        1
     5      28   TH                 196.669890      7.034030        1
     6      30   TH                 270.693430       .990882        1
     7      42   TH                  25.000000       .786697        1
     8      44   TH                 628.747040      1.588479        1
     9      47   TH                 197.945380       .106744        1

 SYNOPSYS AI>
```

APPENDIX G

Back-up BVM Design 60F* with 60 cm Telescope & Fabry-Perot Filter

spe

LENS SPECIFICATION
ID EXBVM

1147

OBJ. DIST.	INFINITE	FOCAL LENGTH	15895.0854
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	275.5780
MARG. RAY HEIGHT	304.8000	PARAXIAL FOCAL P.	278.2667
CHIEF RAY HEIGHT	-.9076	OVERALL LENGTH	3150.7016
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	650.0007
CHIEF RAY ANGLE	.0800	EXIT PUPIL POS.	112.7367
F/NUMBER	26.0746	GAUSSIAN IM. HT.	21.8333

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 3
LENS IS FOCAL, MAGNIFICATION -.156369E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	.00100	BK7	1.51987T	678.41 SCHOTT
2	INFINITE	650.00000	AIR		
3	-2116.20220	-714.92781	-AIR		
CONIC B	.434985E+05				
AXES A	-.959435E+04	CC	-.104865E+01		
4	-884.97698	1696.79270	AIR		
CONIC B	.487741E+03				
AXES A	-.656993E+03	CC	-.281444E+01		
5	466.39000	3.00000	BASF2	1.67153T	407.08 SCHOTT
6	58.29400	8.00000	SK6	1.61790T	611.10 SCHOTT
7	-107.46000	150.00000	AIR		
8	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	50.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-16.50000	-AIR		
20	-90.41700	-7.30000	BK7	-1.51987T	678.41 SCHOTT
21	78.29800	-3.50000	F2	-1.62654T	411.47 SCHOTT
22	558.31000	-55.63153	-AIR		
23	141.25000	-4.80000	SF5	-1.68067T	368.78 SCHOTT
24	47.31500	-3.00000	BK7	-1.51987T	678.41 SCHOTT
25	-61.74800	-462.94824	-AIR		
26	INFINITE	-.00010	BK7	-1.51987T	678.41 SCHOTT
27	INFINITE	-48.00000	-AIR		
28	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSUAL
29	INFINITE	-48.00000	-AIR		
30	INFINITE	-.00010	BK7	-1.51987T	678.41 SCHOTT
31	INFINITE	-65.00000	-AIR		
32A	INFINITE	.00000	AIR		

33A	INFINITE	47.01663	AIR		
34	486.97000	20.00000	BK7	1.51987T	678.41 SCHOTT
35	-354.81000	12.00000	SF5	1.68067T	368.78 SCHOTT
36	-1059.30000	669.18448	AIR		
37	INFINITE	4.00000	FUSILICA	1.46104T	712.58 UNUSUAL
38	INFINITE	12.00000	AIR		
39	INFINITE	21.00000	FUSILICA	1.46104T	712.58 UNUSUAL
40	INFINITE	.00028	AIR		
41	INFINITE	18.00000	FUSILICA	1.46104T	712.58 UNUSUAL
42	INFINITE	.00000	AIR		
43	INFINITE	21.00000	FUSILICA	1.46104T	712.58 UNUSUAL
44	INFINITE	12.00000	AIR		
45	INFINITE	4.00000	FUSILICA	1.46104T	712.58 UNUSUAL
46	INFINITE	456.88659	AIR		
47	1059.30000	12.00000	SF5	1.68067T	368.78 SCHOTT
48	354.81000	20.00000	BK7	1.51987T	678.41 SCHOTT
49	-486.97000	604.09771	AIR		
50	151.57808	8.50000	BK7	1.51987T	678.41 SCHOTT
51	-112.14899	4.33000	SF5	1.68067T	368.78 SCHOTT
52	-335.97070	275.57802	AIR		
53	INFINITE	2.68863	AIR		

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

TILTS AND DECENTERS
X-DECN,YDECN,ZDECN ALPHA,BETA,GAMMA,AXIS

18 TDC 70 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
19 TDC 70 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
32 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
33 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		

SYNOPSYS AI>cap

CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

1	305.708	
2	305.708	
3	304.831	
4	100.438	
5	20.0000	USER-ENTERED CAO
6	20.0000	USER-ENTERED CAO
7	20.0000	USER-ENTERED CAO
8	12.5000	USER-ENTERED CAO
9	12.5000	USER-ENTERED CAO
10	12.5000	USER-ENTERED CAO
11	12.5000	USER-ENTERED CAO

```
      12        12.5000      USER-ENTERED CAO
      13        12.5000      USER-ENTERED CAO
      14        12.5000      USER-ENTERED CAO
      15        12.5000      USER-ENTERED CAO
      16        12.5000      USER-ENTERED CAO
      17        12.6000      USER-ENTERED CAO
      18        19.6706
      19        13.4110
      20        20.0000      USER-ENTERED CAO
      21        20.0000      USER-ENTERED CAO
      22        20.0000      USER-ENTERED CAO
      23        15.7500      USER-ENTERED CAO
      24        15.7500      USER-ENTERED CAO
      25        15.7500      USER-ENTERED CAO
      26        44.4390
      27        44.4390
      28        47.8707
      29        48.3349
      30        51.7667
      31        51.7667
      32        85.9242
      33        56.4138
      34        75.0000      USER-ENTERED CAO
      35        75.0000      USER-ENTERED CAO
      36        75.0000      USER-ENTERED CAO
      37        60.0000      USER-ENTERED CAO
      38        57.2598
      39        60.0000      USER-ENTERED CAO
      40        57.5228
      41        60.0000      USER-ENTERED CAO
      42        57.6456
      43        60.0000      USER-ENTERED CAO
      44        57.7889
      45        60.0000      USER-ENTERED CAO
      46        57.9359
      47        75.0000      USER-ENTERED CAO
      48        75.0000      USER-ENTERED CAO
      49        75.0000      USER-ENTERED CAO
      50        20.3200      USER-ENTERED CAO
      51        20.3200      USER-ENTERED CAO
      52        20.3200      USER-ENTERED CAO
      53        22.1950
SYNOPSYS AI>
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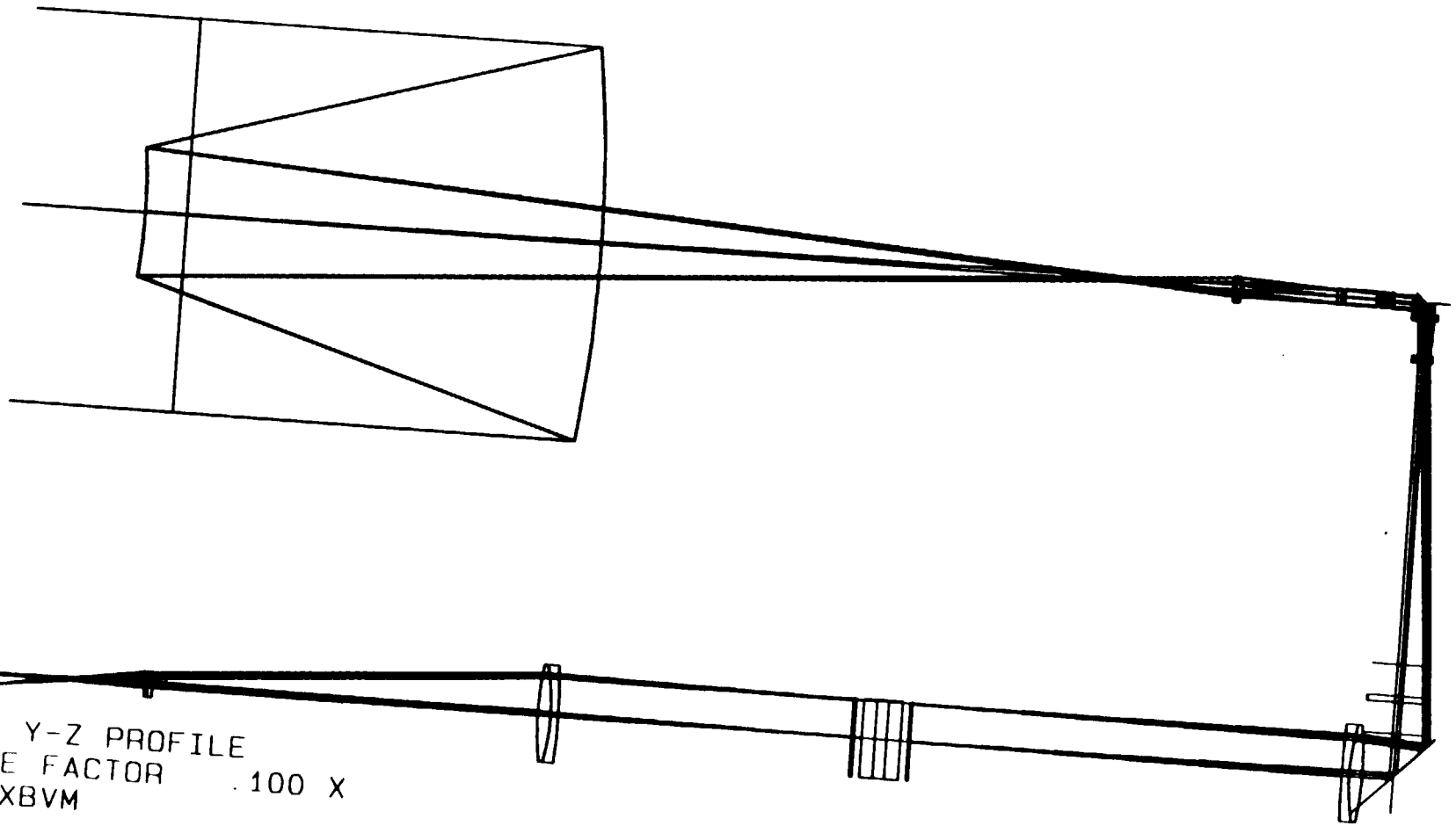
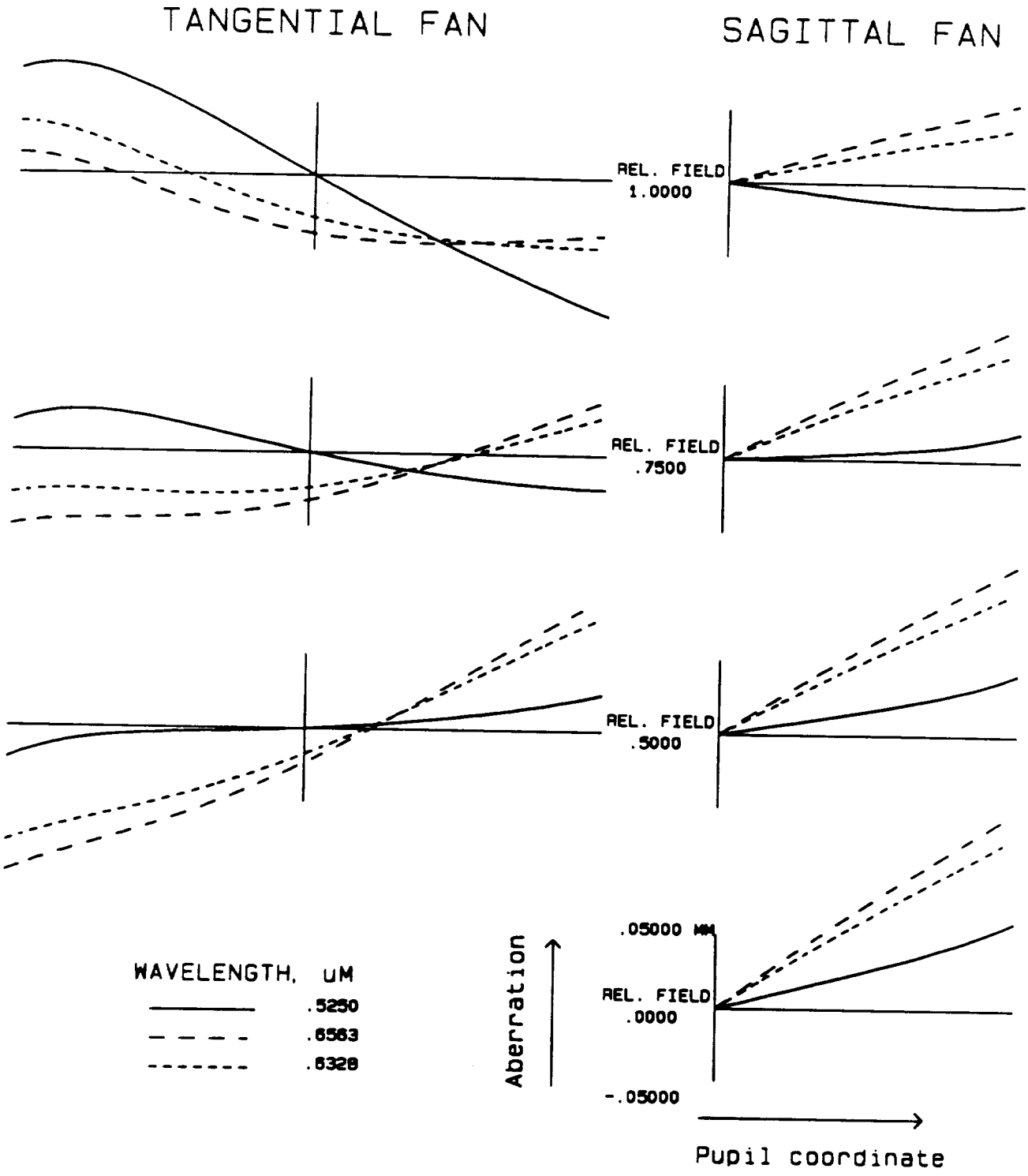


LENS Y-Z PROFILE
SCALE FACTOR .100 X
ID EXBVM

7-Apr-92 11:42:13

TRANSVERSE ABERRATION

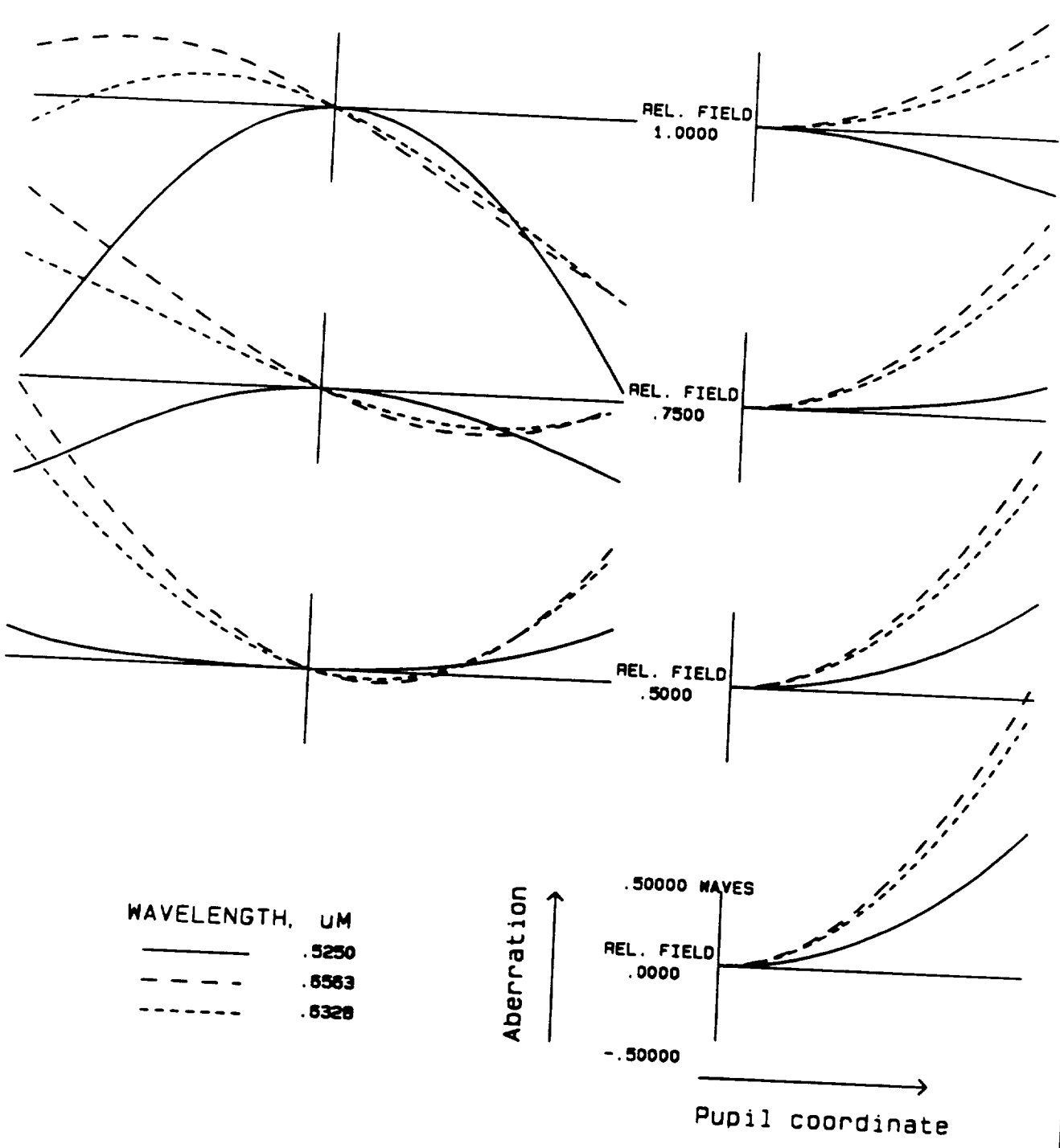


ID EXBVM

1147

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM 7-Apr-92 11:44:14

OPTICAL PATH DIFFERENCE



ID EXBVM

1147

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM 7-Apr-92 11:43:16

APPENDIX H

BVM Design 60B with 60 cm Telescope & Birefringent Filter

SPE

LENS SPECIFICATION
ID EXBVMB1

1147

OBJ. DIST.	INFINITE	FOCAL LENGTH	14324.5094
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	436.8244
MARG. RAY HEIGHT	304.8000	PARAXIAL FOCAL P.	436.9935
CHIEF RAY HEIGHT	-.4189	OVERALL LENGTH	2124.4131
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	300.0000
CHIEF RAY ANGLE	.0800	EXIT PUPIL POS.	-96.7799
F/NUMBER	23.4982	GAUSSIAN IM. HT.	19.9945

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 2
LENS IS FOCAL, MAGNIFICATION -.143200E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	300.00000	AIR		
2	-2162.50820	-728.58410	-AIR		
CONIC B	-.338062E+05				
AXES A	.855022E+04	CC	-.936032E+00		
3	-864.73471	2102.56020	AIR		
CONIC B	.115815E+04				
AXES A	-.100075E+04	CC	-.174665E+01		
4	229.10424	3.00000	BASF2	1.67153T	407.08 SCHOTT
5	55.82163	1.00000	AIR		
6	57.03947	8.00000	SK6	1.61790T	611.10 SCHOTT
7	-188.79066	175.00000	AIR		
8	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	25.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-25.00000	-AIR		
20	-210.75002	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63402	-185.00000	-AIR		
23	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSUAL
24	INFINITE	-60.00000	-AIR		
25A	INFINITE	.00000	AIR		
26A	INFINITE	18.22284	AIR		
27	36.10985	5.00000	LASFN15	1.88680T	426.15 SCHOTT
28	-688.09583	5.50000	AIR		
29	-68.72670	3.00000	FK5	1.49012T	736.70 SCHOTT
30	29.06472	5.00000	AIR		
31	INFINITE	300.00000	CALCITE	1.66356T	529.15 UNUSUAL
32	INFINITE	57.60002	AIR		

33	118.25309	5.00000	LAK21	1.64456T	642.16	SCHOTT
34	-121.19061	30.01415	AIR			
35	-63.99026	5.00000	SF58	1.93387T	256.49	SCHOTT
36	-108.04208	436.82440	AIR			
37	INFINITE	.16907	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

2	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.13505E-16	.00000E+00	.00000E+00	.00000E+00	-.10534E-21
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.32467E-27	.00000E+00			
3	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.11120E-13	.00000E+00	.00000E+00	.00000E+00	-.82312E-18
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.23829E-22	.00000E+00			

TILTS AND DECENTERS
X-DECN,YDECN,ZDECN ALPHA,BETA,GAMMA,AXIS

18	TDC	50	SURFACES		
.450000E+02		.000000E+00	.000000E+00	.000000E+00	
.000000E+00		.000000E+00	.000000E+00		
19	TDC	50	SURFACES		
.450000E+02		.000000E+00	.000000E+00	.000000E+00	
.000000E+00		.000000E+00	.000000E+00		
25	TDC	50	SURFACES		
.450000E+02		.000000E+00	.000000E+00	.000000E+00	
.000000E+00		.000000E+00	.000000E+00		
26	TDC	50	SURFACES		
.450000E+02		.000000E+00	.000000E+00	.000000E+00	
.000000E+00		.000000E+00	.000000E+00		

SYNOPSYS AI>CAP

CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

1	305.219	
2	304.830	
3	100.801	
4	20.0000	USER-ENTERED CAO
5	18.7985	
6	20.0000	USER-ENTERED CAO
7	20.0000	USER-ENTERED CAO
8	12.5000	USER-ENTERED CAO
9	12.5000	USER-ENTERED CAO
10	12.5000	USER-ENTERED CAO
11	12.5000	USER-ENTERED CAO
12	12.5000	USER-ENTERED CAO
13	12.5000	USER-ENTERED CAO
14	12.5000	USER-ENTERED CAO
15	12.5000	USER-ENTERED CAO
16	12.5000	USER-ENTERED CAO
17	12.5000	USER-ENTERED CAO

```
      18       18.2850
      19       12.3884
      20       15.0000      USER-ENTERED CAO
      21       15.0000      USER-ENTERED CAO
      22       15.0000      USER-ENTERED CAO
      23       23.0000      USER-ENTERED CAO
      24       23.0000      USER-ENTERED CAO
      25       17.9885
      26       12.6779
      27       12.6105
      28       12.1548
      29       10.4168
      30       9.46809
      31       12.5000      USER-ENTERED CAO
      32       12.5000      USER-ENTERED CAO
      33       13.8729
      34       13.9130
      35       12.2757
      36       12.6338
      37       20.2329
SYNOPSYS AI>
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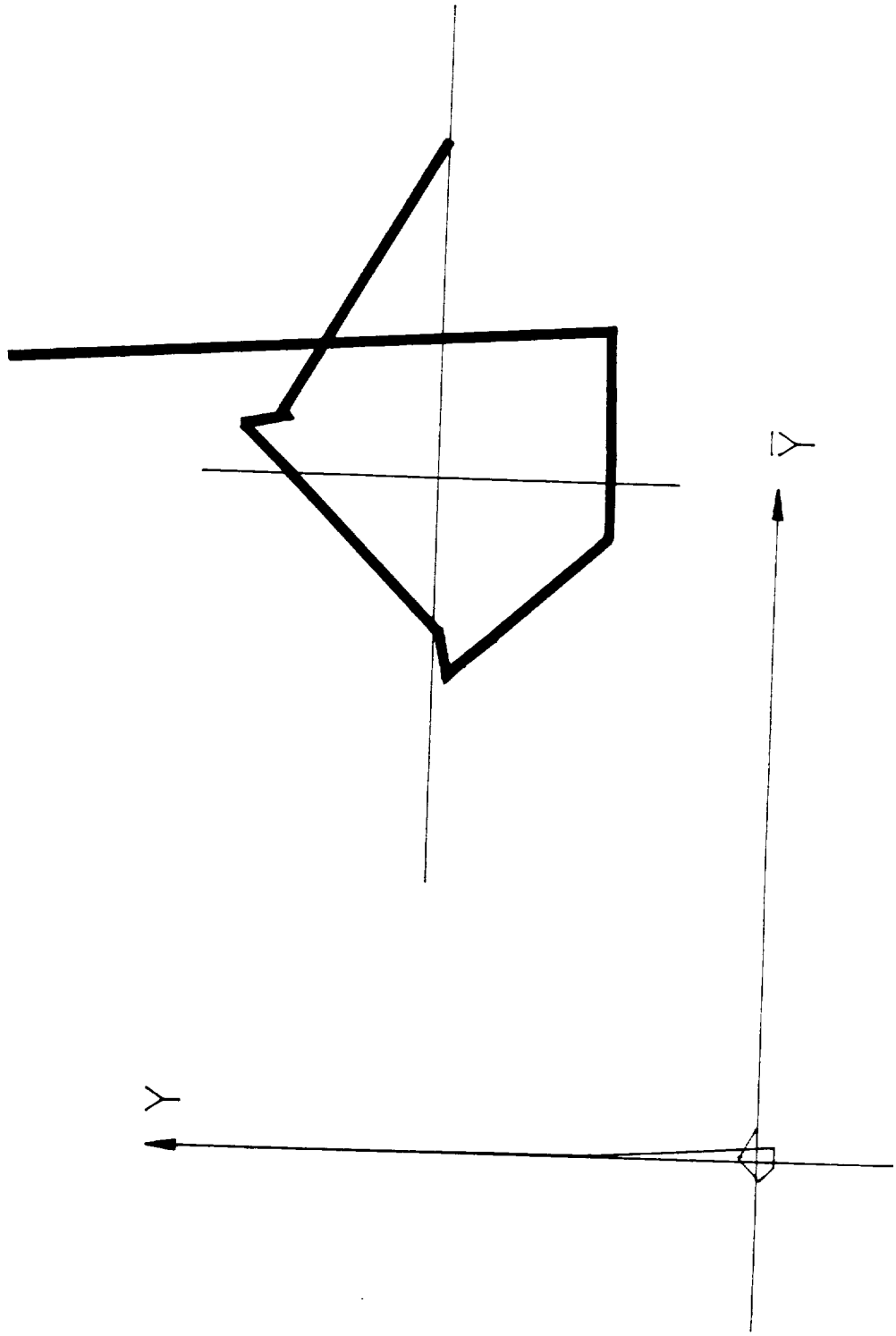
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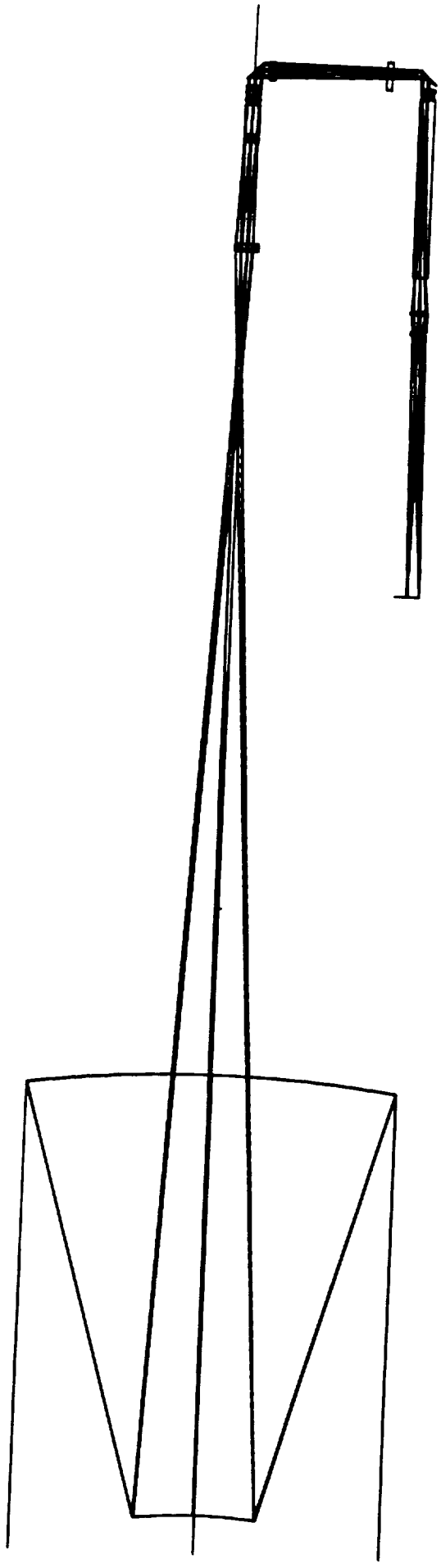
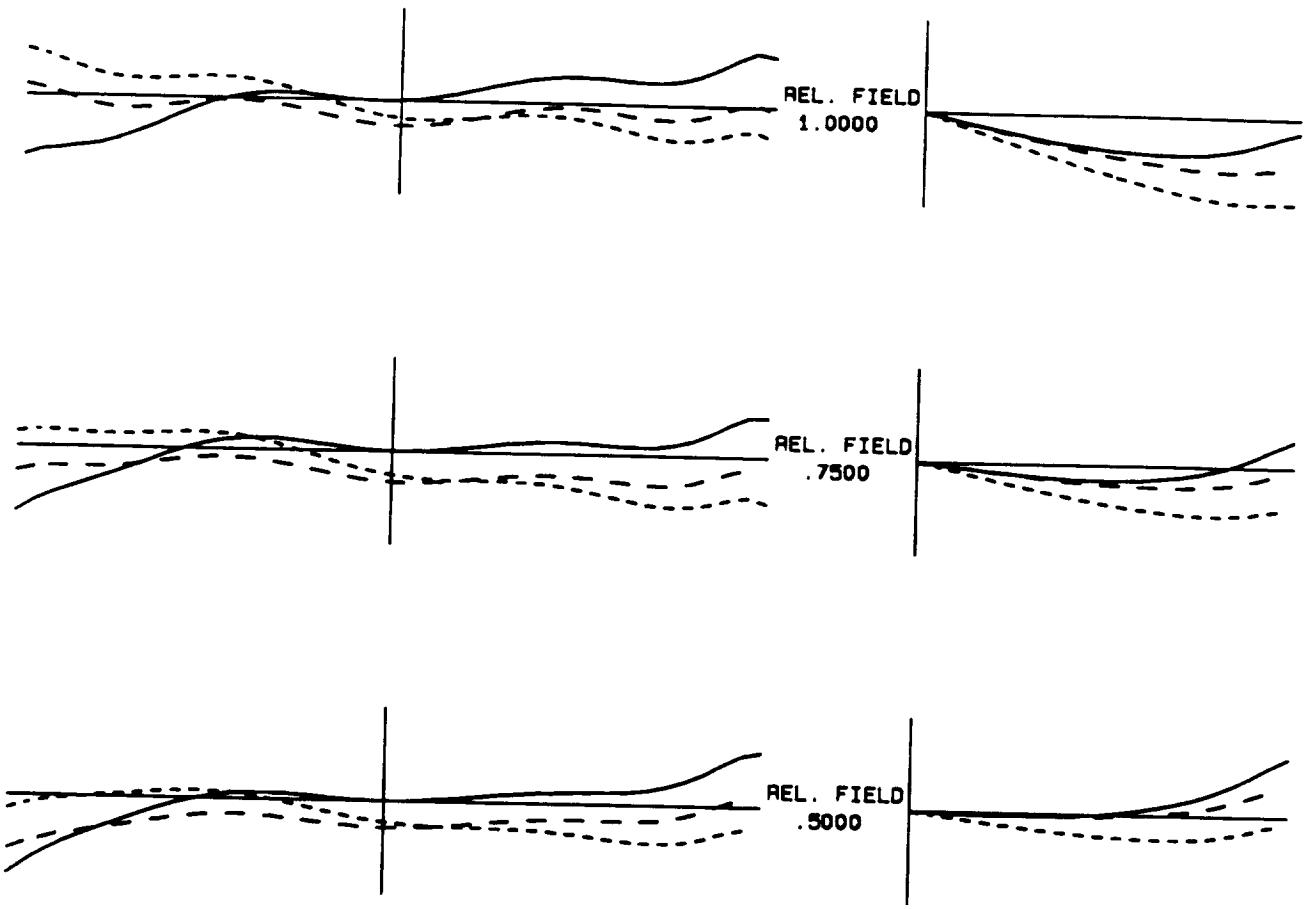
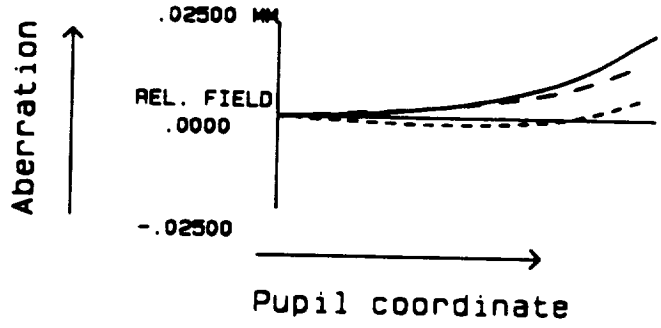


TRANSVERSE ABERRATION



WAVELENGTH, uM

———	.5250
– – – –	.6563
-------	.6328

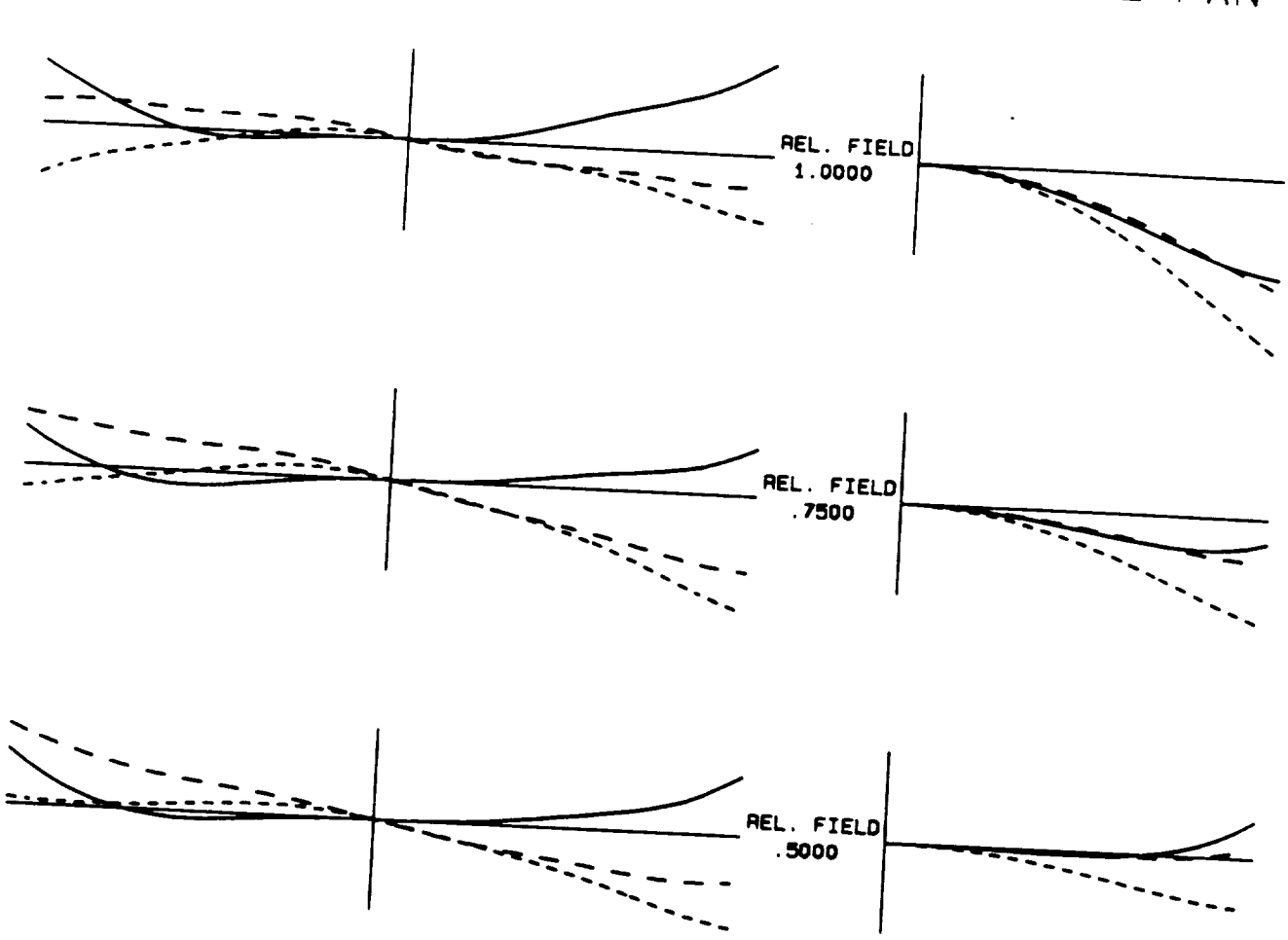


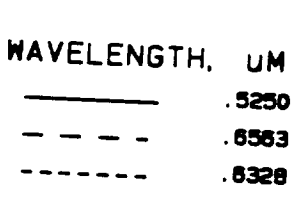
ID EXBVMB1

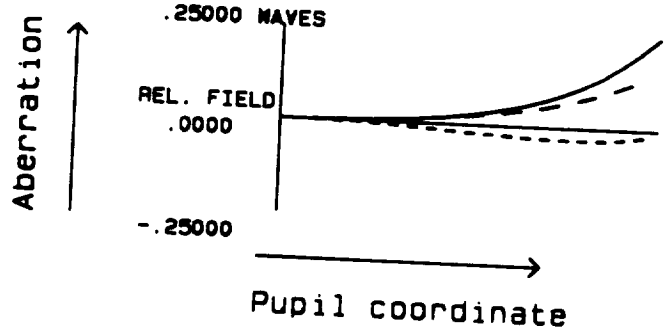
1147

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM 19-May-92 11:23:03

OPTICAL PATH DIFFERENCE





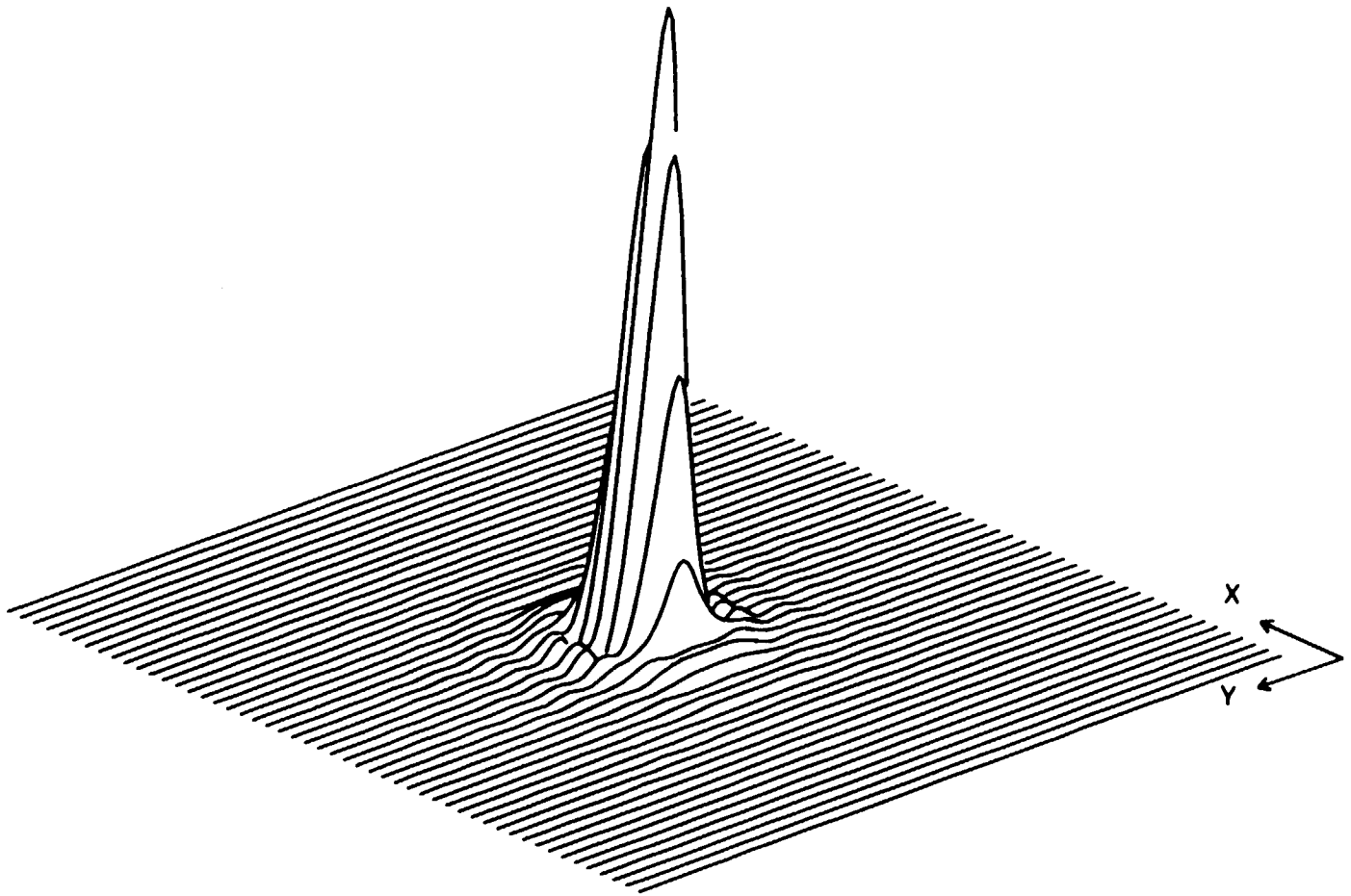


ID EXBVMB1

1147

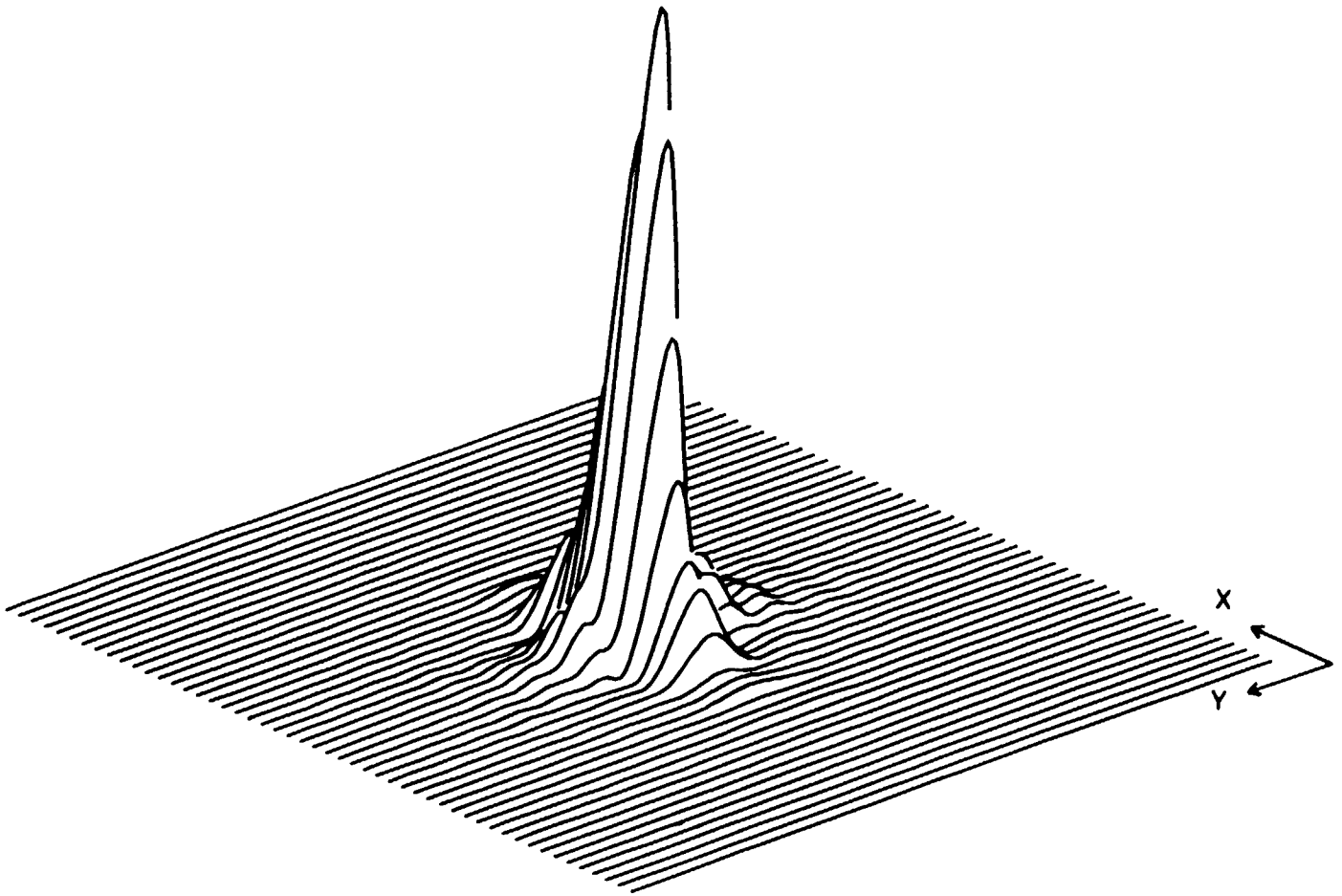
SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM 19-May-92 11:22:05

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .015048 MM ID EXBVMB1
PSPRD 2 0 300 0 0.WAVELENGTH .52502
FRACTIONAL FIELD .0000 .0000
SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

DIFFRACTION INTENSITY PATTERN



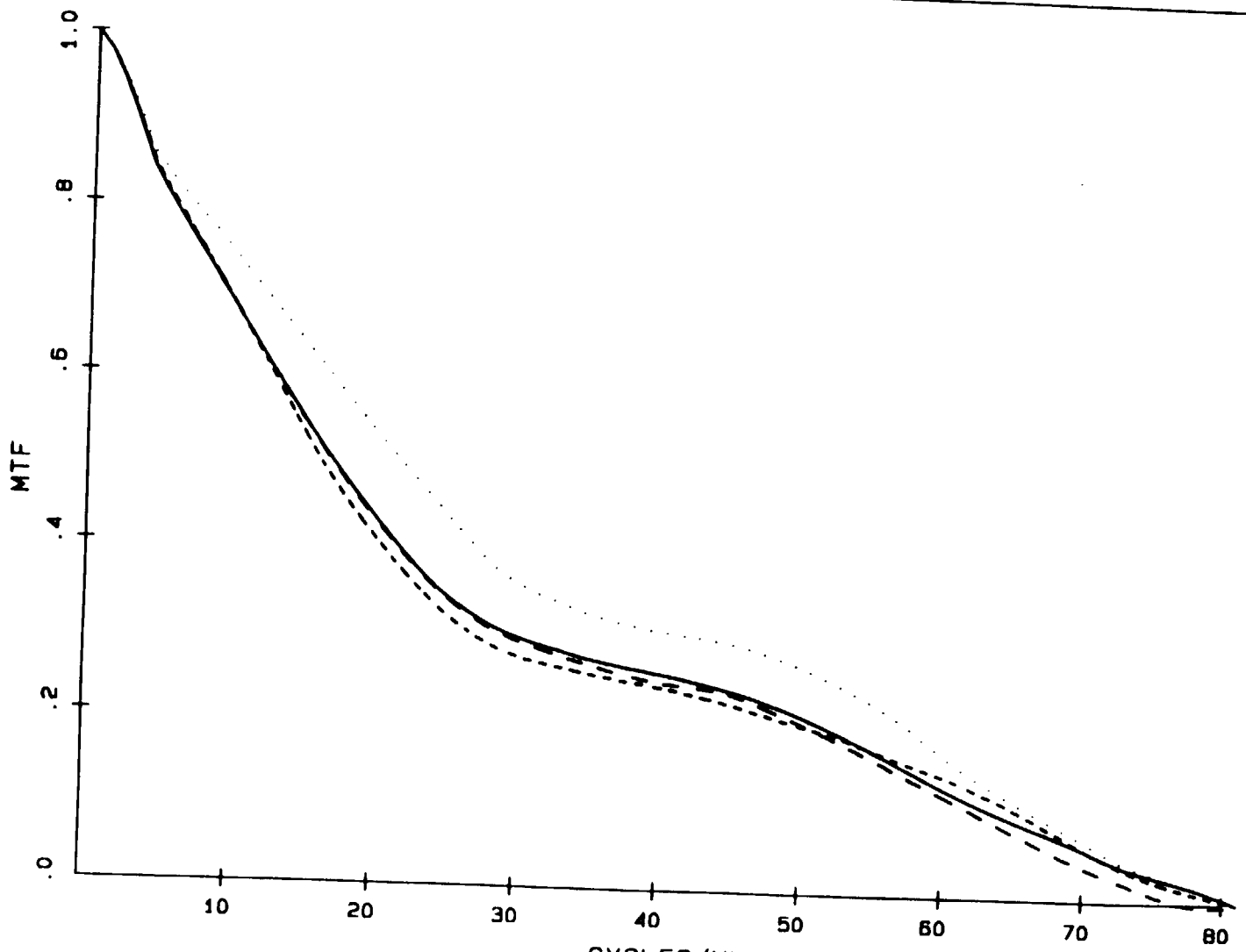
AIRY DISK RADIUS .015639 MM ID EXBVMB1
PSPRD 2 1. 300 0 0. WAVELENGTH .52502 1147
FRACTIONAL FIELD 1.0000 .0000
SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

19-May-92 11:25:47

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. .0000 FIELD 1.0000 FIELD
SAG.

WAVELENGTH	WEIGHT
.52502	1.000



ID EXBVMB1
SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM
1147
DEFOCUS -.169073

SPE

LENS SPECIFICATION
ID EXBVMB2

OBJ. DIST.	INFINITE	FOCAL LENGTH	26846.0047
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	436.8244
MARG. RAY HEIGHT	304.8000	PARAXIAL FOCAL P.	438.1713
CHIEF RAY HEIGHT	-.2094	OVERALL LENGTH	2124.4131
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	300.0000
CHIEF RAY ANGLE	.0400	EXIT PUPIL POS.	69.7228
F/NUMBER	44.0387	GAUSSIAN IM. HT.	18.6735

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 2
LENS IS FOCAL, MAGNIFICATION -.267479E-06
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	300.00000	AIR		
2	-2162.50820	-728.58410	-AIR		
CONIC B	-.338062E+05				
AXES A	.855022E+04	CC	-.936032E+00		
3	-864.73471	2102.56020	AIR		
CONIC B	.115815E+04				
AXES A	-.100075E+04	CC	-.174665E+01		
4	229.10424	3.00000	BASF2	1.67153T	407.08 SCHOTT
5	55.82163	1.00000	AIR		
6	57.03947	8.00000	SK6	1.61790T	611.10 SCHOTT
7	-188.79066	175.00000	AIR		
8	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	25.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-25.00000	-AIR		
20	-210.75002	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63402	-60.00000	-AIR		
23	-120.15000	-5.21000	BK7	-1.51987T	678.41 SCHOTT
24	76.21000	-2.90000	SF5	-1.68067T	368.78 SCHOTT
25	201.90000	-57.83696	-AIR		
26	75.53100	-3.20000	SF5	-1.68067T	368.78 SCHOTT
27	24.40600	-1.50000	BK7	-1.51987T	678.41 SCHOTT
28	-30.28700	130.64696G	-AIR		
29	INFINITE	-185.00000	-AIR		
30	INFINITE	-9.50000	FUSILICA	-1.46104T	712.58 UNUSUAL
31	INFINITE	-60.00000	-AIR		
32A	INFINITE	.00000	AIR		

33A	INFINITE	18.22284	AIR			
34	36.10985	5.00000	LASFN15	1.88680T	426.15	SCHOTT
35	-688.09583	5.50000	AIR			
36	-68.72670	3.00000	FK5	1.49012T	736.70	SCHOTT
37	29.06472	5.00000	AIR			
38	INFINITE	300.00000	CALCITE	1.66356T	529.15	UNUSUAL
39	INFINITE	57.60002	AIR			
40	118.25309	5.00000	LAK21	1.64456T	642.16	SCHOTT
41	-121.19061	30.01415	AIR			
42	-63.99026	5.00000	SF58	1.93387T	256.49	SCHOTT
43	-108.04208	436.82440	AIR			
44	INFINITE	1.34687	AIR			

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

2	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.13505E-16	.00000E+00	.00000E+00	.00000E+00	-.10534E-21
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.32467E-27	.00000E+00			
3	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.11120E-13	.00000E+00	.00000E+00	.00000E+00	-.82312E-18
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.23829E-22	.00000E+00			

TILTS AND DECENTERS
X-DECN,YDECN,ZDECN ALPHA,BETA,GAMMA,AXIS

18 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
19 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
29 COINCIDENT WITH SURFACE 22				
32 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		
33 TDC 50 SURFACES				
.450000E+02	.000000E+00	.000000E+00	.000000E+00	
.000000E+00	.000000E+00	.000000E+00		

SYNOPSYS AI>CAP

CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

1	305.009	
2	304.815	
3	100.285	
4	20.0000	USER-ENTERED CAO
5	14.3490	
6	20.0000	USER-ENTERED CAO
7	20.0000	USER-ENTERED CAO
8	12.5000	USER-ENTERED CAO
9	12.5000	USER-ENTERED CAO

```
    10      12.5000      USER-ENTERED CAO
    11      12.5000      USER-ENTERED CAO
    12      12.5000      USER-ENTERED CAO
    13      12.5000      USER-ENTERED CAO
    14      12.5000      USER-ENTERED CAO
    15      12.5000      USER-ENTERED CAO
    16      12.5000      USER-ENTERED CAO
    17      12.5000      USER-ENTERED CAO
    18      16.3087
    19      11.2906
    20      15.0000      USER-ENTERED CAO
    21      15.0000      USER-ENTERED CAO
    22      15.0000      USER-ENTERED CAO
    23      15.0000      USER-ENTERED CAO
    24      15.0000      USER-ENTERED CAO
    25      15.0000      USER-ENTERED CAO
    26      9.00000      USER-ENTERED CAO
    27      9.00000      USER-ENTERED CAO
    28      9.00000      USER-ENTERED CAO
    29      9.72254
    30      23.0000      USER-ENTERED CAO
    31      23.0000      USER-ENTERED CAO
    32      14.8197
    33      10.0996
    34      10.8197
    35      10.4053
    36      9.11354
    37      8.50925
    38      12.5000      USER-ENTERED CAO
    39      12.5000      USER-ENTERED CAO
    40      11.5601
    41      11.4433
    42      8.08885
    43      8.11260
    44      18.8846
SYNOPSYS AI>
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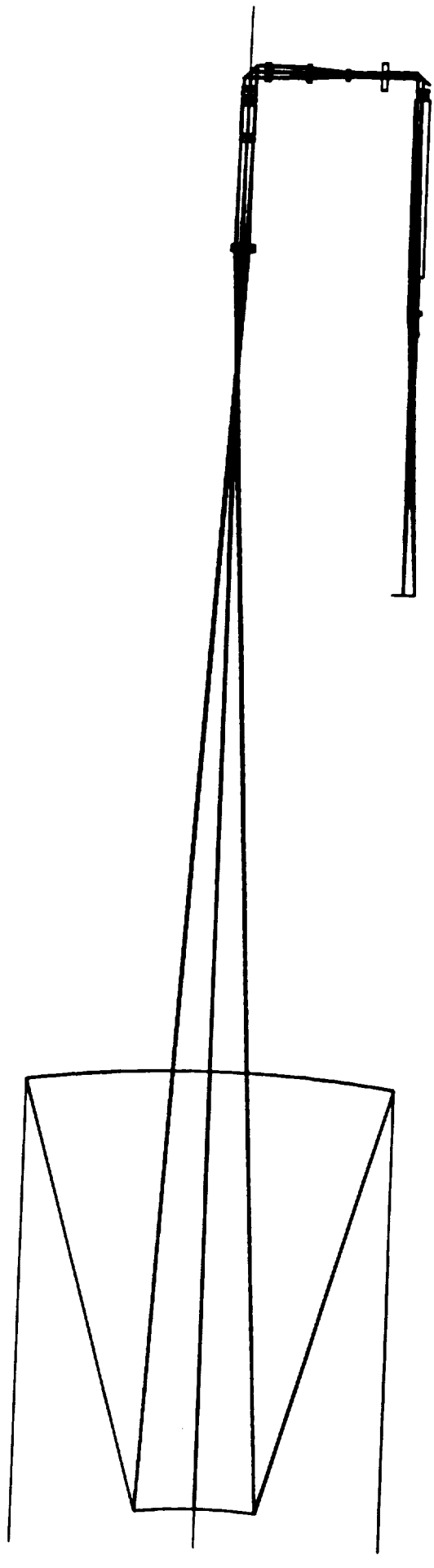
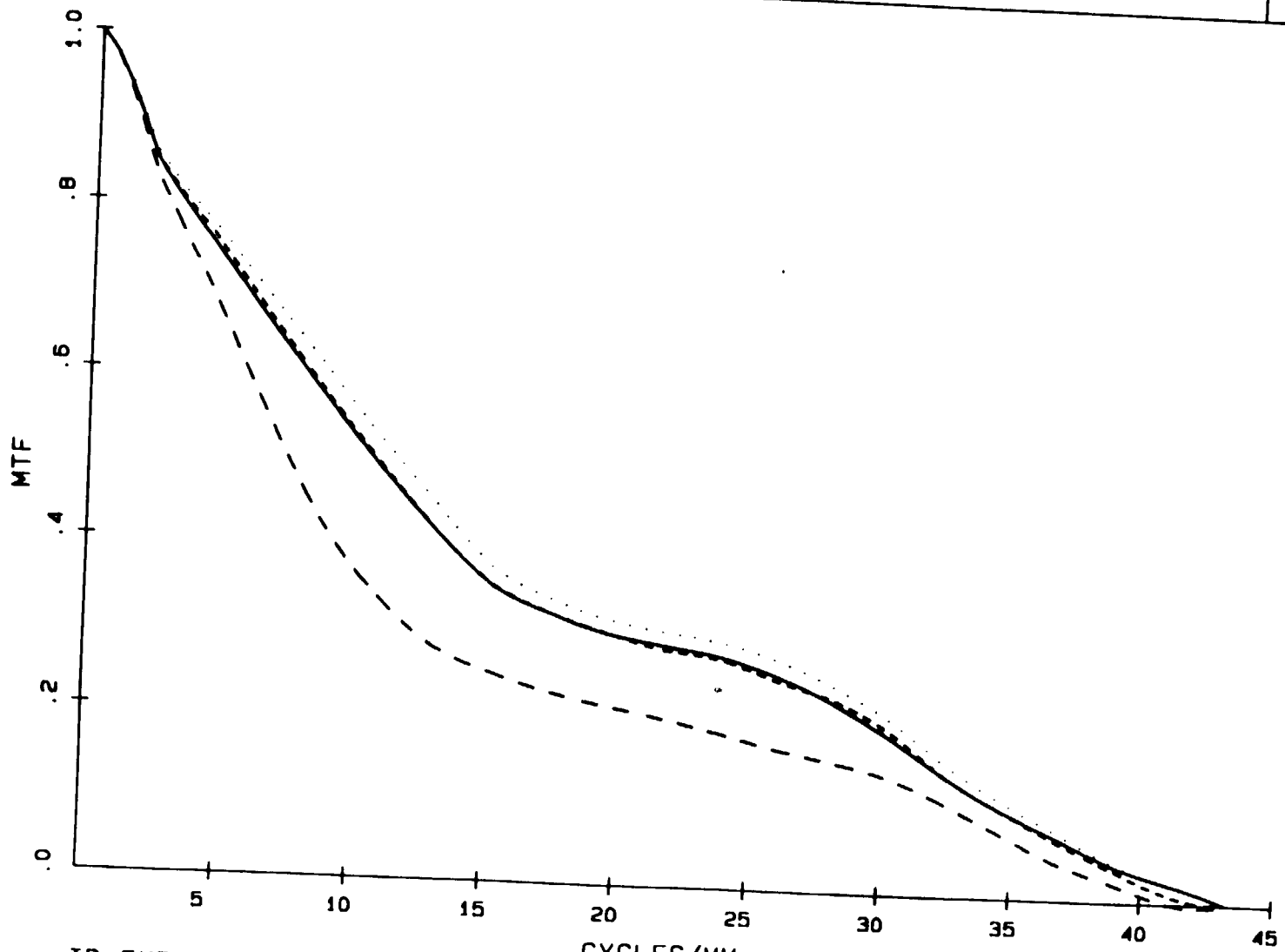


MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN.
SAG.

.0000 FIELD
1.0000 FIELD

WAVELENGTH	WEIGHT
.52502	1.000



ID EX8VM82

SEMI-FIELD = .0400 DEGREES SEMI-APERTURE = 304.8000 MM

DEFOCUS -1.346870

Tolerance for EXBVMB1

```
GDS

PANT

CALL  PANT

CALL  PANT
VLIST TH 2 3 5   22 26 28 32 34 36
END
CALL  AANT
GNV 0 1 4 2

***      26 RAYS GENERATED IN COLOR      2 AT HBAR       .0000 GBAR       .0000
END
CALL  TOL .76281E-02


TOLERANCE CALCULATIONS
CRITERION ON ABERRATIONS      .007628


VARIABLE LIST
NO.   SN  PAR                UPPER LIMIT      LOWER LIMIT       INCREMENT
 1     2   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 2     3   TH      .10000000E+05    .00000000E+00    .10000000E-02
 3     5   TH      .10000000E+05    .00000000E+00    .10000000E-02
 4    22   TH      .00000000E+00   -.10000000E+05    .10000000E-02
 5    26   TH      .10000000E+05    .00000000E+00    .10000000E-02
 6    28   TH      .10000000E+05    .00000000E+00    .10000000E-02
 7    32   TH      .10000000E+05    .00000000E+00    .10000000E-02
 8    34   TH      .10000000E+05    .00000000E+00    .10000000E-02
 9    36   TH      .10000000E+05    .00000000E+00    .10000000E-02

SYSTEM ABERRATIONS
      1    .15742437E+00
      2    .53741614E-01
      3    .14205498E-01
      4    .23394756E-02
      5    .23394756E-02
      6    .14205498E-01
      7    .53741614E-01
      8    .15742437E+00
      9    .20675548E+00
     10    .81836581E-01
     11    .31215747E-01
     12    .14205498E-01
     13    .14205498E-01
     14    .31215747E-01
     15    .81836581E-01
     16    .20675548E+00
     17    .15742437E+00
     18    .81836581E-01
     19    .53741614E-01
     20    .53741614E-01
     21    .81836581E-01
     22    .15742437E+00
     23    .20675548E+00
     24    .15742437E+00
     25    .15742437E+00
```

```
      26     .20675548E+00
   1  TOTAL     .50853866E-02
 INITIAL MERIT FUNCTION    .258612E-04
   -.728583E+03     .728642E-04
   -.728583E+03     .568456E-04    1


 TOLERANCE, PARAMETER NO.    1

  2  TH          -728.584100
  1      .753960E-02  *
 EXTREME VALUE      -728.583363    TOLERANCE          -.000737

    .210256E+04     .248225E-04
    .210254E+04     .635831E-04    1


 TOLERANCE, PARAMETER NO.    2

  3  TH          2102.560200
  1      .797390E-02  *
 EXTREME VALUE      2102.535553    TOLERANCE           .024647

   .100100E+01     .184469E-04
   .996783E+00     .655343E-04    1
   .997783E+00     .501741E-04
   .997245E+00     .580575E-04    1


 TOLERANCE, PARAMETER NO.    3

  5  TH             1.000000
  1      .761955E-02  *
 EXTREME VALUE          .997245    TOLERANCE           .002755

   -.184999E+03     .263154E-04
   -.184943E+03     .632032E-04    1


 TOLERANCE, PARAMETER NO.    4

 22  TH          -185.000000
  1      .795004E-02  *
 EXTREME VALUE      -184.942821    TOLERANCE          -.057179

   .182238E+02     .254129E-04
   .181654E+02     .634334E-04    1


 TOLERANCE, PARAMETER NO.    5

 26  TH            18.222840
  1      .796451E-02  *
 EXTREME VALUE        18.165402    TOLERANCE           .057438

   .550100E+01     .246149E-04
   .547950E+01     .636000E-04    1


 TOLERANCE, PARAMETER NO.    6
```

```
   28  TH              5.500000
    1      .797496E-02  *
   EXTREME VALUE         5.479501   TOLERANCE          .020499

      .576010E+02      .249589E-04
      .575716E+02      .635378E-04   1


 TOLERANCE, PARAMETER NO.    7

   32  TH             57.600019
    1      .797106E-02  *
   EXTREME VALUE        57.571609   TOLERANCE          .028410

      .300151E+02      .236851E-04
      .300025E+02      .638741E-04   1


 TOLERANCE, PARAMETER NO.    8

   34  TH             30.014148
    1      .799213E-02  *
   EXTREME VALUE        30.002519   TOLERANCE          .011629

      .436825E+03      .256844E-04
      .436678E+03      .633708E-04   1


 TOLERANCE, PARAMETER NO.    9

   36  TH            436.824400
    1      .796057E-02  *
   EXTREME VALUE       436.678309   TOLERANCE          .146091

   TOLERANCE SUMMARY
 VAR. NO.                          VALUE          TOLERANCE  LIM. ABRN.

     1      2  TH                -728.584100       -.000737        1
     2      3  TH                2102.560200        .024647        1
     3      5  TH                   1.000000        .002755        1
     4     22  TH                -185.000000       -.057179        1
     5     26  TH                  18.222840        .057438        1
     6     28  TH                   5.500000        .020499        1
     7     32  TH                  57.600019        .028410        1
     8     34  TH                  30.014148        .011629        1
     9     36  TH                 436.824400        .146091        1

 SYNOPSYS AI>
```

APPENDIX I

BVM Design 60C
Correlation Tracker path
for 60 cm Telescope

SPE

LENS SPECIFICATION
ID EXBVMCT

1147

OBJ. DIST.	INFINITE	FOCAL LENGTH	-8979.4580
OBJ. HEIGHT	INFINITE	BACK FOCAL DIST.	266.4249
MARG. RAY HEIGHT	304.8000	PARAXIAL FOCAL P.	266.4249
CHIEF RAY HEIGHT	-.4189	OVERALL LENGTH	1914.5761
MARG. RAY ANGLE	.0000	ENTR. PUPIL POS.	300.0000
CHIEF RAY ANGLE	.0800	EXIT PUPIL POS.	-141.1367
F/NUMBER	-14.7301	GAUSSIAN IM. HT.	-12.5377

WAVELENGTHS .65627 .52502 .63280
UNITS MM
STOP IS ON SURF. NO. 2
LENS IS FOCAL, MAGNIFICATION .897946E-07
GLOBAL OPTION IS ON
POLARIZATION AND COATINGS ARE IGNORED.

SURF. NO.	RADIUS	THICKNESS	MEDIUM		
1	INFINITE	300.00000	AIR		
2	-2162.50820	-728.58410	-AIR		
CONIC B	-.338062E+05				
AXES A	.855022E+04	CC	-.936032E+00		
3	-864.73471	2102.56020	AIR		
CONIC B	.115815E+04				
AXES A	-.100075E+04	CC	-.174665E+01		
4	229.10424	3.00000	BASF2	1.67153T	407.08 SCHOTT
5	55.82163	1.00000	AIR		
6	57.03947	8.00000	SK6	1.61790T	611.10 SCHOTT
7	-188.79066	175.00000	AIR		
8	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
9	INFINITE	5.00000	AIR		
10	INFINITE	50.00000	CALCITE	1.66356T	529.15 UNUSUAL
11	INFINITE	5.00000	AIR		
12	INFINITE	6.00000	BK7	1.51987T	678.41 SCHOTT
13	INFINITE	5.00000	AIR		
14	INFINITE	7.00000	CRQZB	1.53483T	707.37 UNUSUAL
15	INFINITE	5.00000	AIR		
16	INFINITE	3.00000	BK7	1.51987T	678.41 SCHOTT
17	INFINITE	25.00000	AIR		
18A	INFINITE	.00000	-AIR		
19A	INFINITE	-25.00000	-AIR		
20	-210.75002	-5.00000	BAK4	-1.57269T	607.06 SCHOTT
21	81.29000	-4.40000	F3	-1.61924T	418.06 SCHOTT
22	515.63402	-30.00000	-AIR		
23A	INFINITE	.00000	AIR		
24A	INFINITE	266.42488S	AIR		
25	INFINITE	.00000	AIR		

NOTE: ITEMS MARKED "P" OR "S" ARE SUBJECT TO PICKUPS OR SOLVES

DEFORMATION COEFFICIENTS

2	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
	.13505E-16	.00000E+00	.00000E+00	.00000E+00	-.10534E-21
	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00

```
        .32467E-27    .00000E+00

    3   .00000E+00    .00000E+00    .00000E+00    .00000E+00    .00000E+00
        .11120E-13    .00000E+00    .00000E+00    .00000E+00   -.82312E-18
        .00000E+00    .00000E+00    .00000E+00    .00000E+00    .00000E+00
        .23829E-22    .00000E+00

  TILTS AND DECENTERS      ALPHA,BETA,GAMMA,AXIS
  X-DECN,YDECN,ZDECN

    18      TDC    50  SURFACES
     .450000E+02        .000000E+00    .000000E+00    .000000E+00
     .000000E+00        .000000E+00    .000000E+00
    19      TDC    50  SURFACES
     .450000E+02        .000000E+00    .000000E+00    .000000E+00
     .000000E+00        .000000E+00    .000000E+00
    23      TDC    10  SURFACES
     .450000E+02        .000000E+00    .000000E+00    .000000E+00
     .000000E+00        .000000E+00    .000000E+00
    24      TDC    10  SURFACES
     .450000E+02        .000000E+00    .000000E+00    .000000E+00
     .000000E+00        .000000E+00    .000000E+00
SYNOPSYS AI>CAP


CLEAR APERTURE RADII

(Y-COORDINATE ONLY)

     1      305.219
     2      304.830
     3      100.801
     4      20.0000      USER-ENTERED CAO
     5      18.7985
     6      20.0000      USER-ENTERED CAO
     7      20.0000      USER-ENTERED CAO
     8      12.5000      USER-ENTERED CAO
     9      12.5000      USER-ENTERED CAO
    10      12.5000      USER-ENTERED CAO
    11      12.5000      USER-ENTERED CAO
    12      12.5000      USER-ENTERED CAO
    13      12.5000      USER-ENTERED CAO
    14      12.5000      USER-ENTERED CAO
    15      12.5000      USER-ENTERED CAO
    16      12.5000      USER-ENTERED CAO
    17      12.5000      USER-ENTERED CAO
    18      18.2850
    19      12.3884
    20      15.0000      USER-ENTERED CAO
    21      15.0000      USER-ENTERED CAO
    22      15.0000      USER-ENTERED CAO
    23      19.0231
    24      13.4071
    25      12.5369
SYNOPSYS AI>
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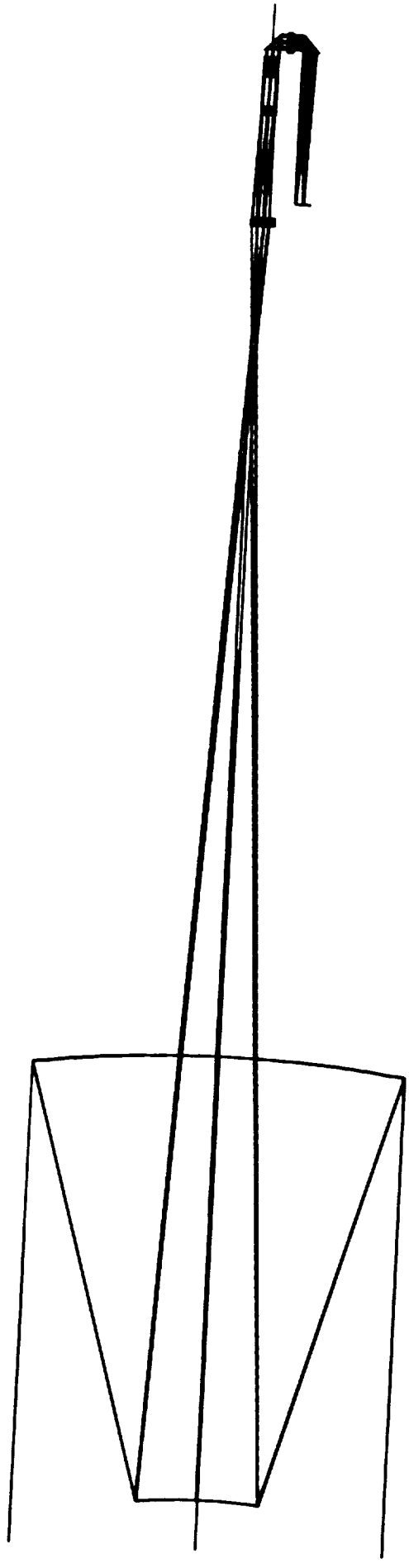
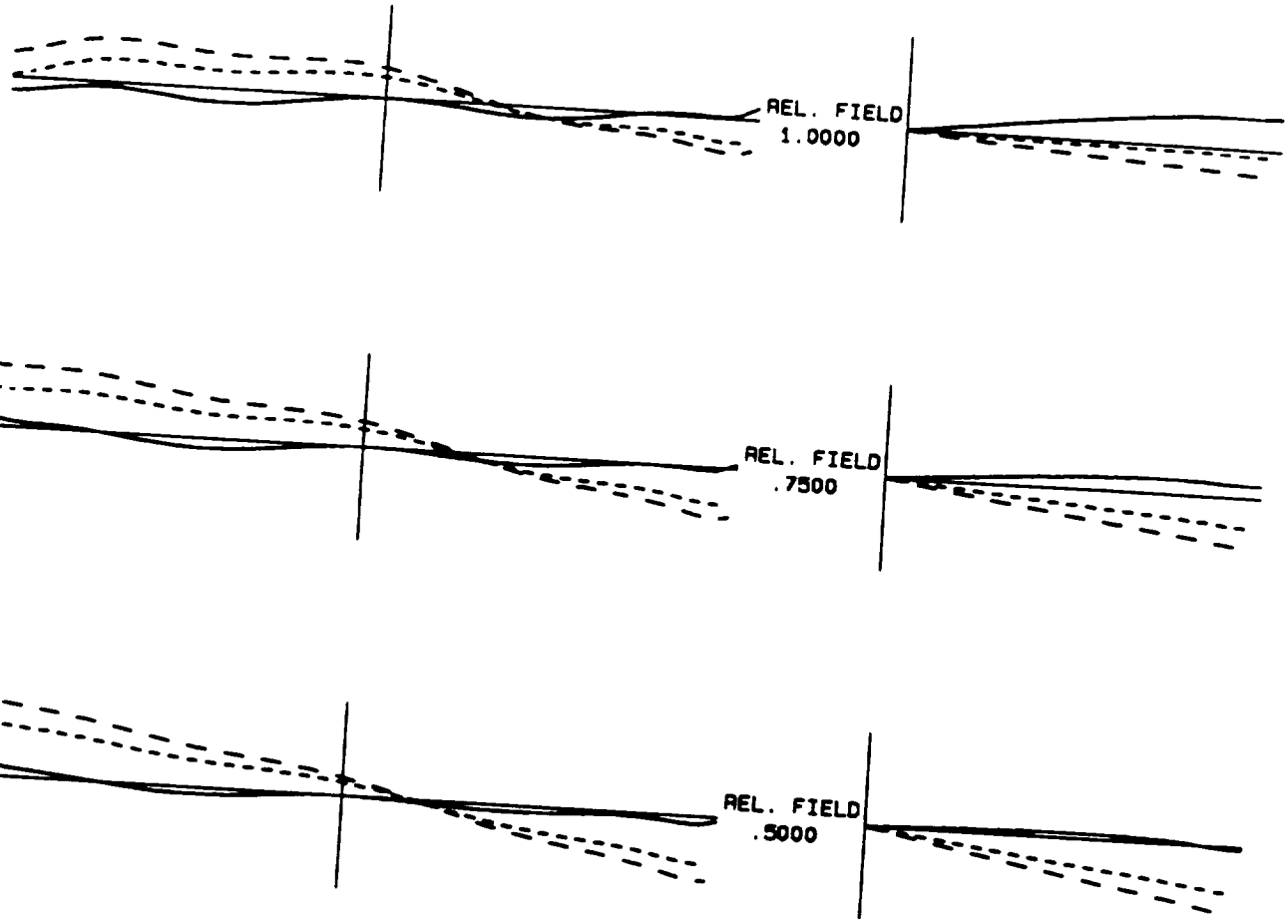


TRANSVERSE ABERRATION

TANGENTIAL FAN

SAGITTAL FAN

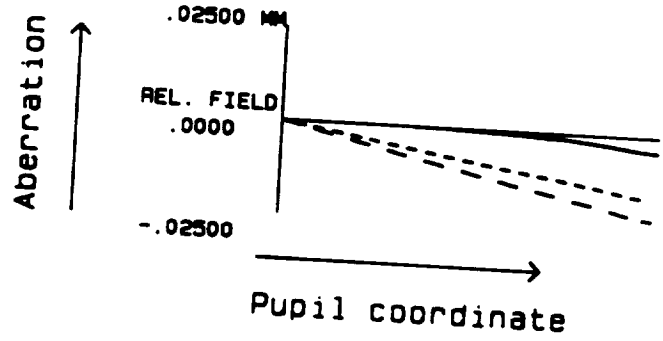


WAVELENGTH, uM

.5250

.6563

.6328



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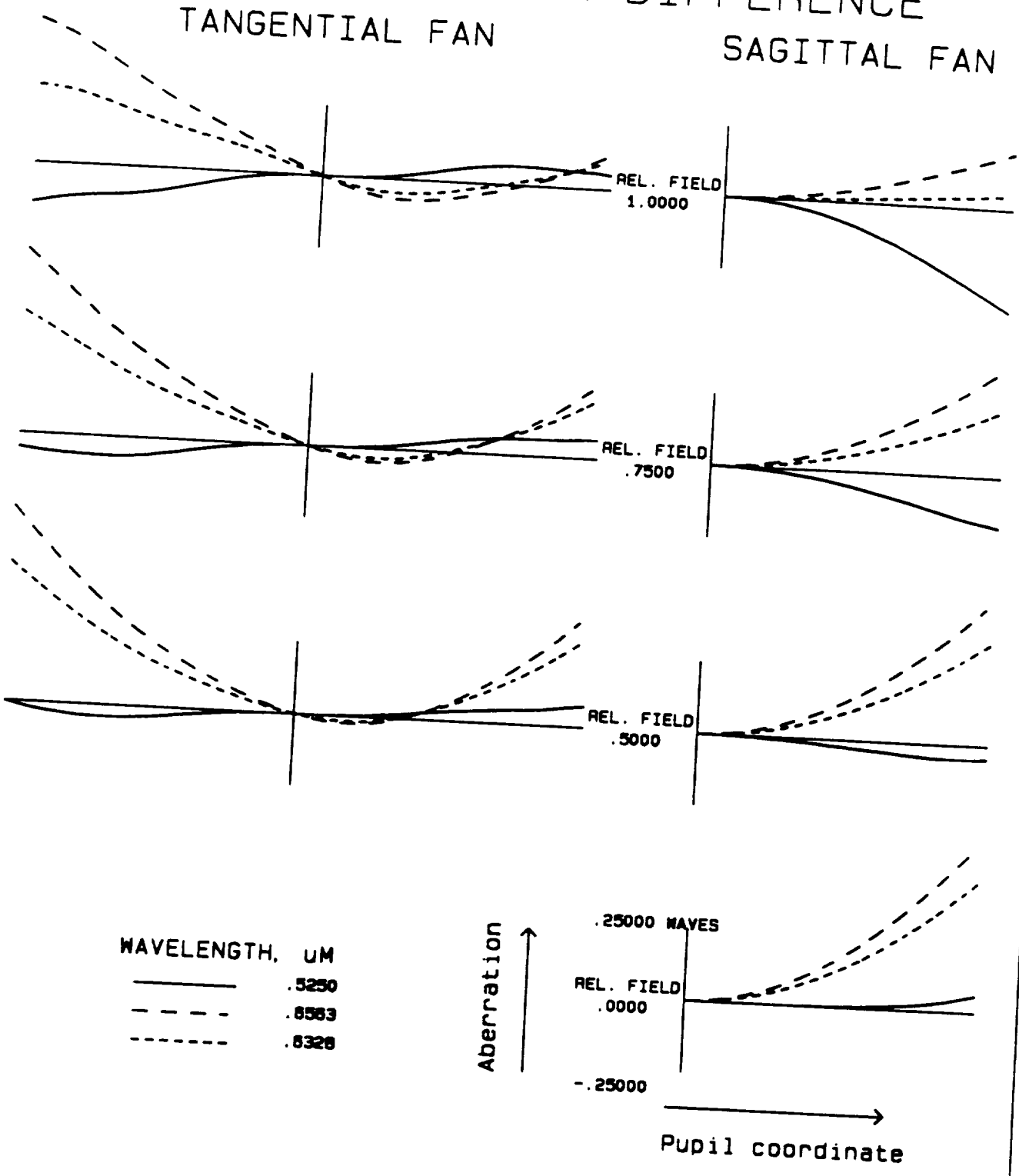
OPTICAL PATH DIFFERENCE



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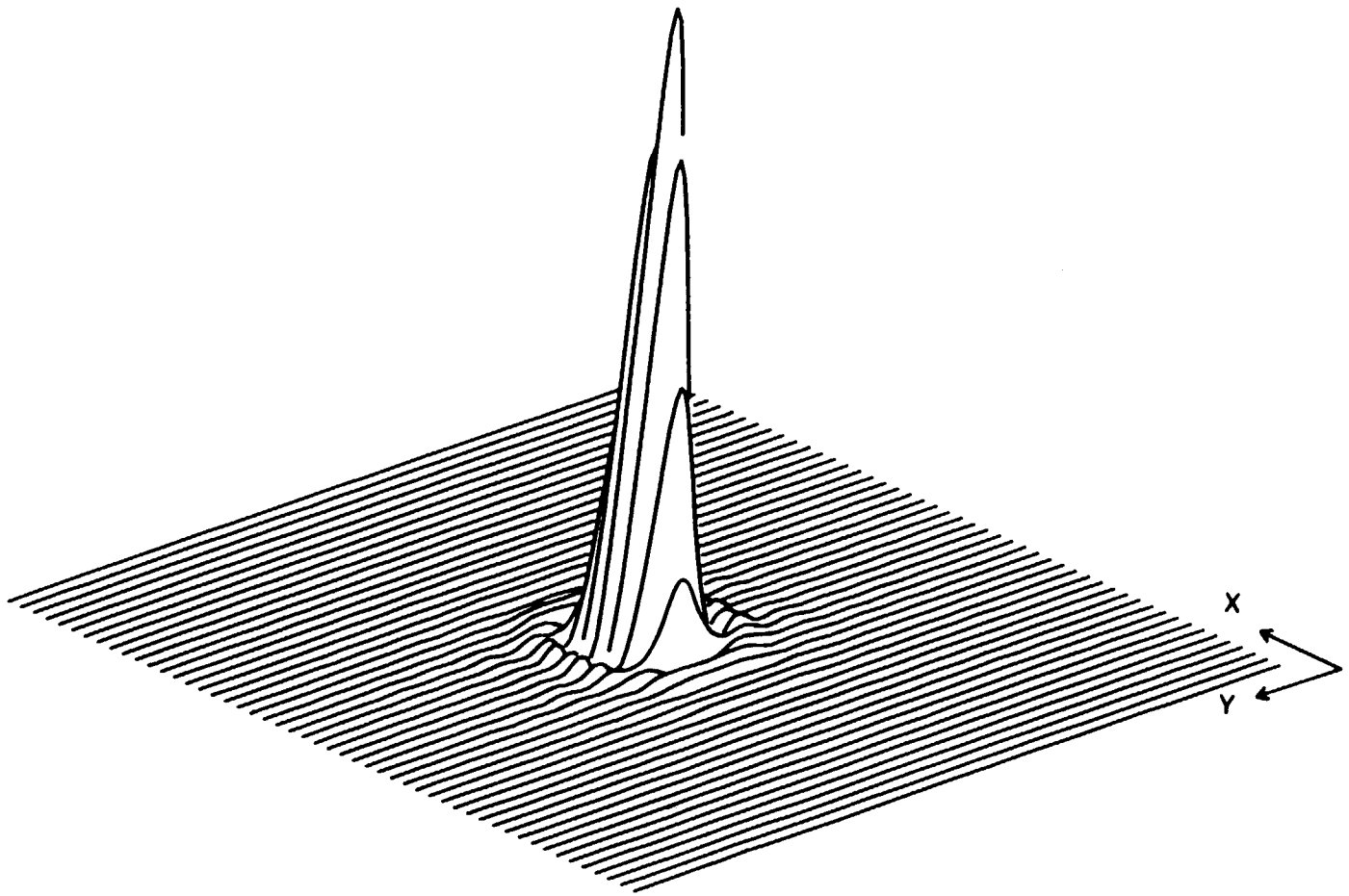
DIFFRACTION INTENSITY PATTERN



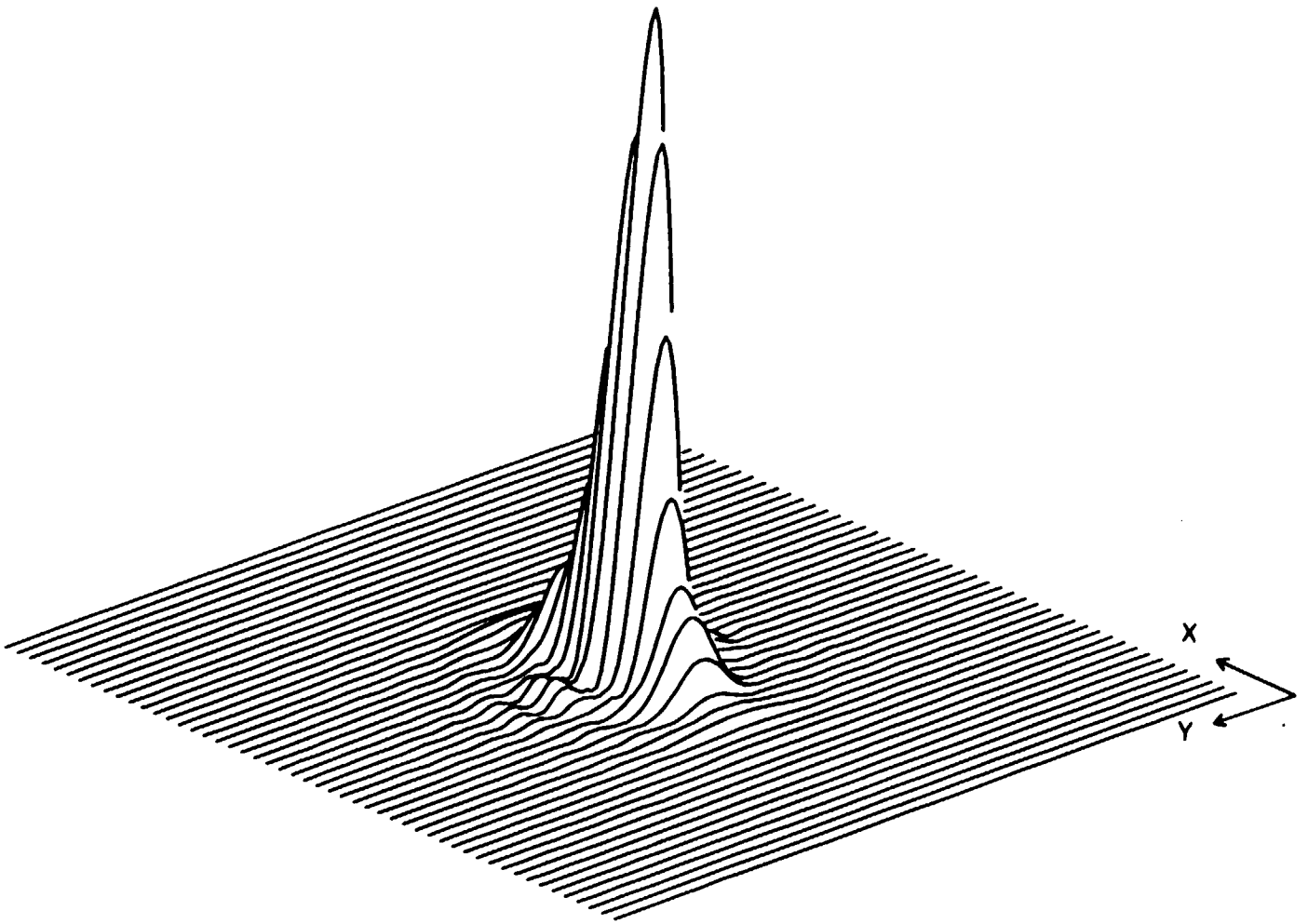
AIRY DISK RADIUS .009433 MM

PSPRD 2 0 300 0 0. ID EXBVMCT

FRACTIONAL FIELD .0000 .0000 WAVELENGTH .52502

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

DIFFRACTION INTENSITY PATTERN



AIRY DISK RADIUS .009418 MM

PSPRD 2 1 300 0 0. ID EXBVMCT

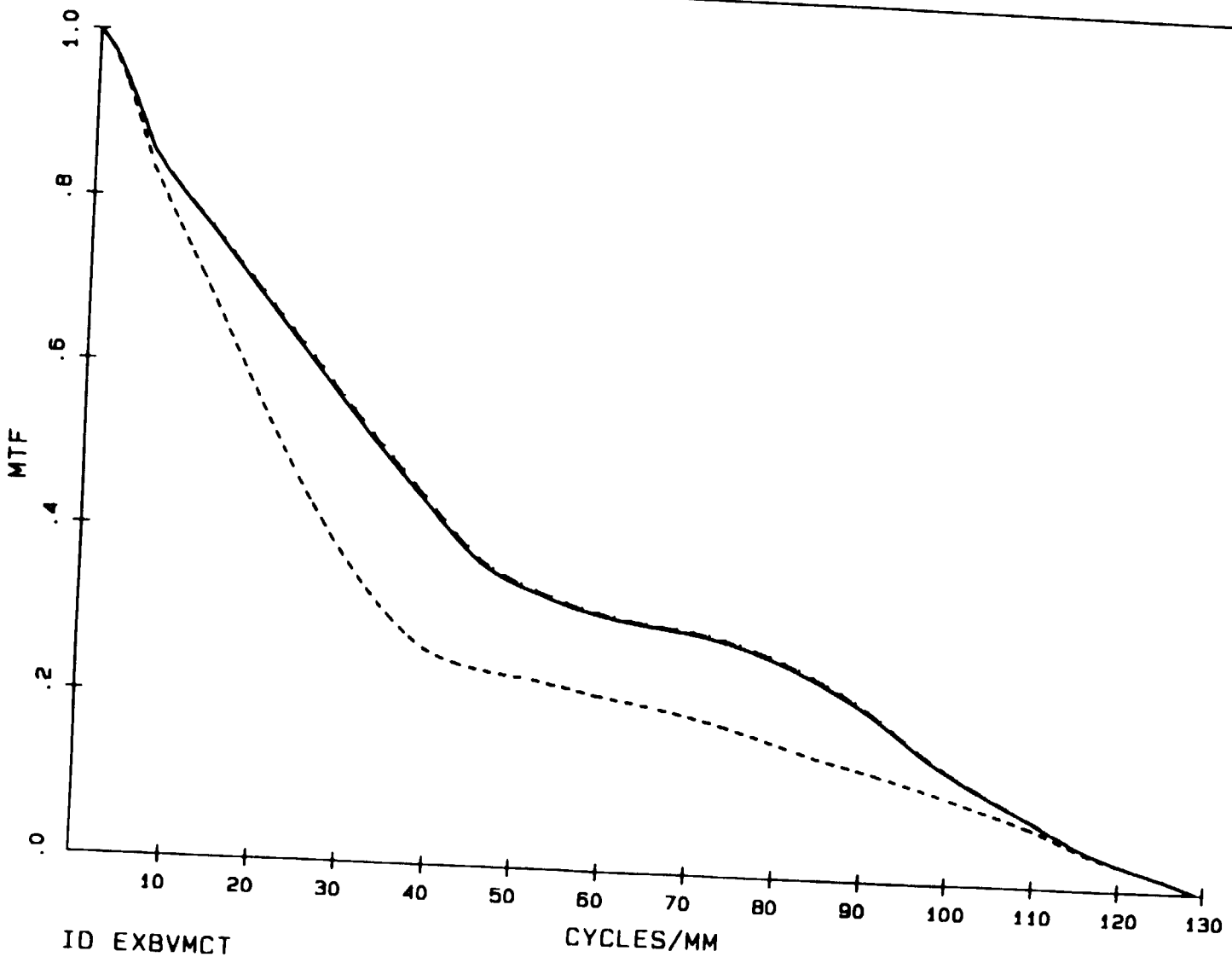
FRACTIONAL FIELD 1.0000 .0000 WAVELENGTH .52502

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN. . . . . .0000 FIELD 1.0000 FIELD
SAG. . . . . .

WAVELENGTH	WEIGHT
.52502	1.000



ID EXBVMCT
SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM

DEFOCUS .000000

APPENDIX J

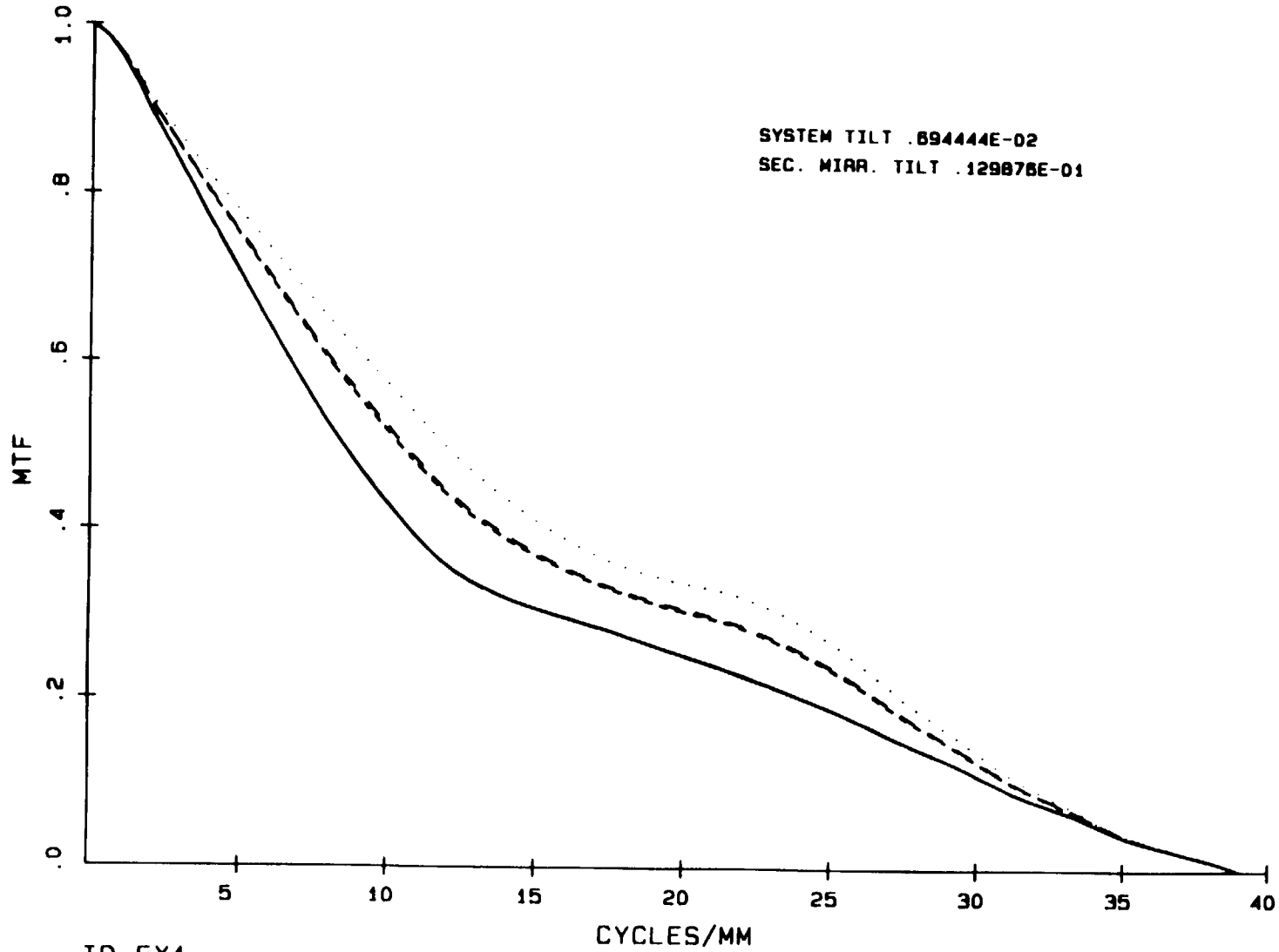
Articulated Secondary Analyses for 30F & 60F Designs

MODULATION TRANSFER FUNCTION

DIFF. LIM.
TAN.
SAG.

.0000 FIELD
1.0000 FIELD

WAVELENGTH	WEIGHT
.52502	1.000



ID EX1

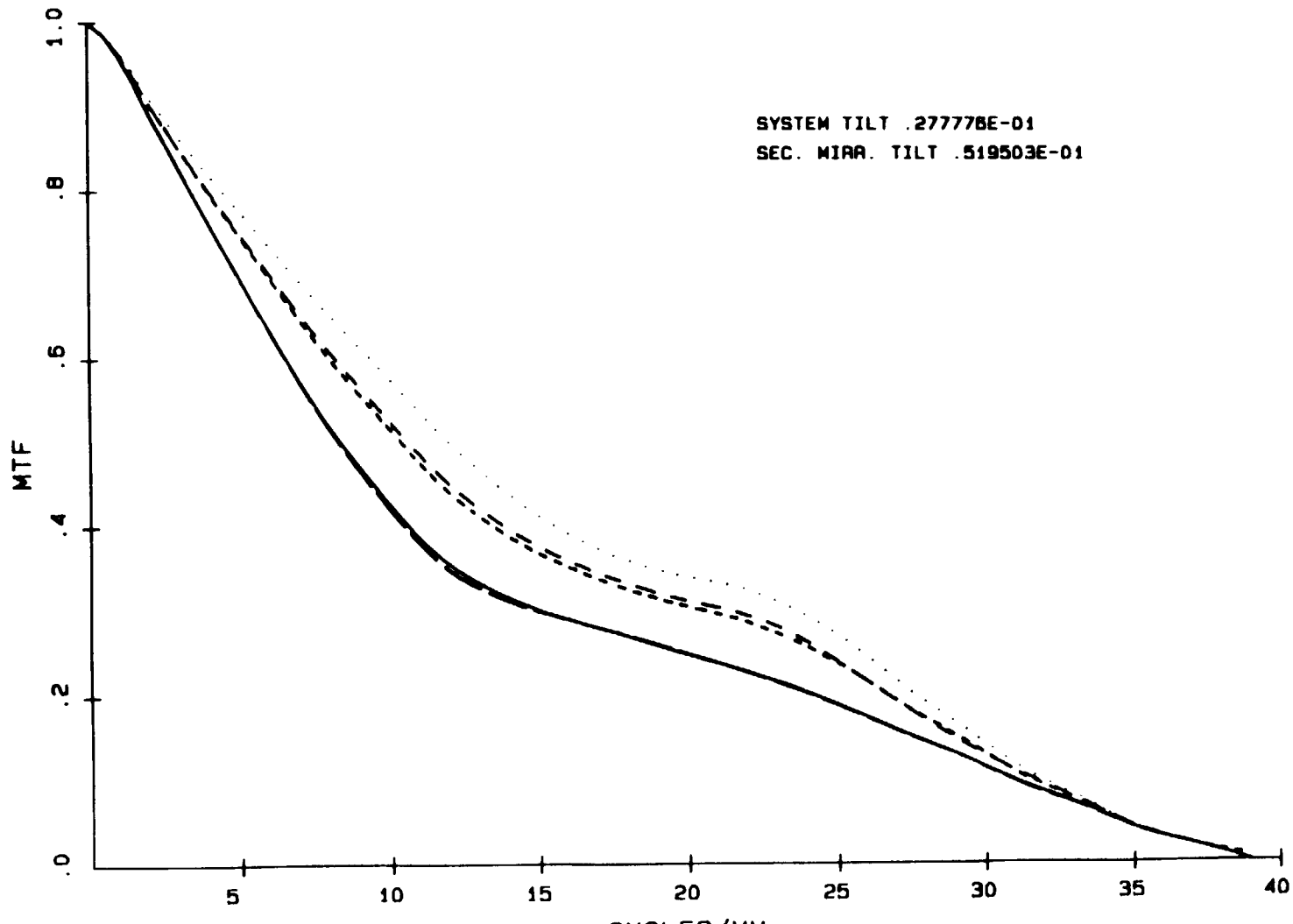
1147

DEFOCUS -3.036473

SEMI-FIELD = .0817 DEGREES SEMI-APERTURE = 152.4000 MM

MODULATION TRANSFER FUNCTION

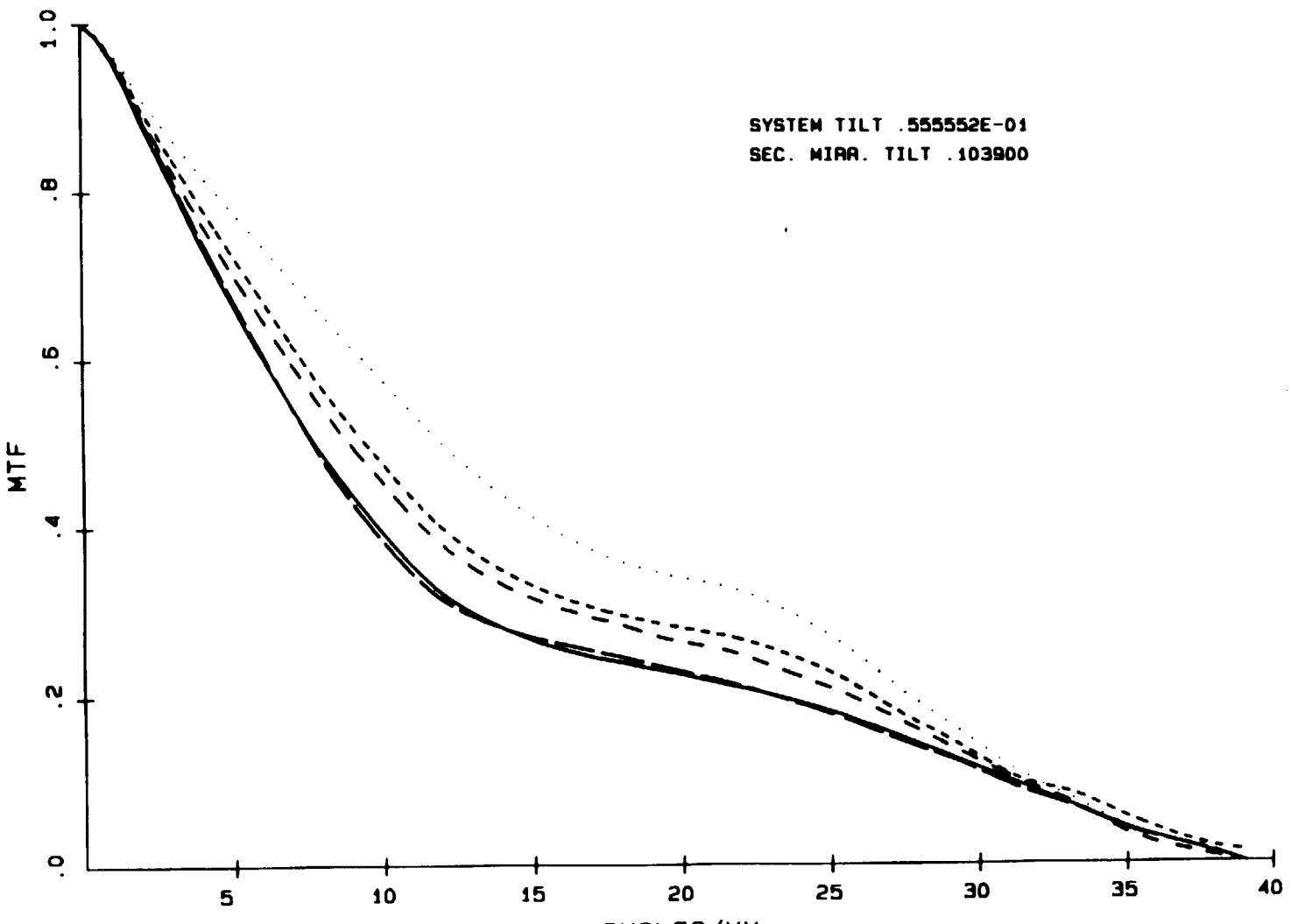
DIFF. LIM.	.0000 FIELD	1.0000 FIELD	WAVELENGTH	WEIGHT
TAN.	———	— — —	.52502	1.000
SAG.	——— ———	- - - - - -		



ID EX1 1147 DEFOCUS -3.036473

MODULATION TRANSFER FUNCTION

DIFF. LIM.	.0000 FIELD	1.0000 FIELD	WAVELENGTH	WEIGHT
TAN.	———	— — —	.52502	1.000
SAG.	——— ———	- - - - - -		



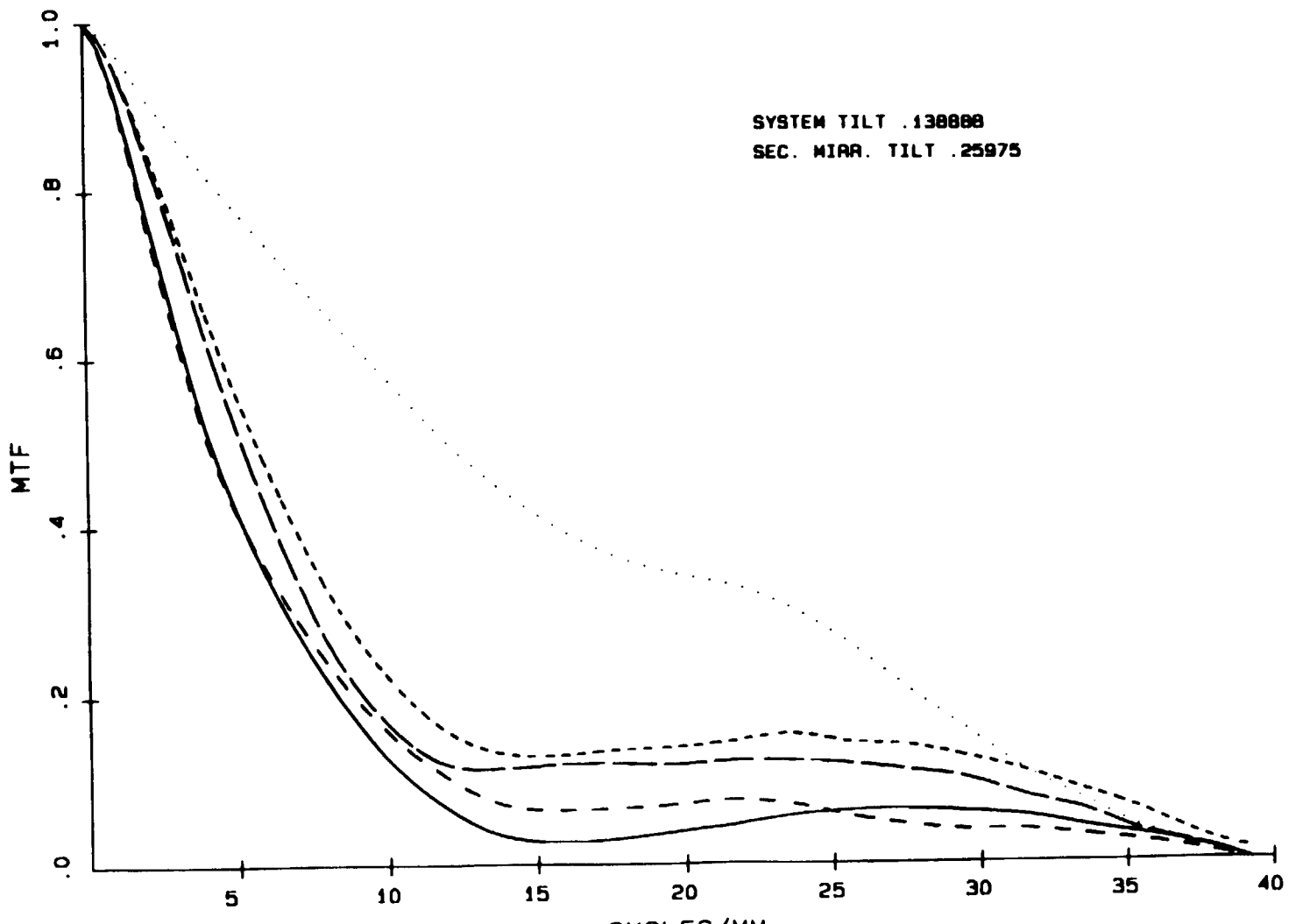
ID EX1

1147

DEFOCUS -3.036473

MODULATION TRANSFER FUNCTION

			WAVELENGTH	WEIGHT
DIFF. LIM.	.0000 FIELD	1.0000 FIELD		
TAN.	———	— — —	.52502	1.000
SAG.	——— ———	- - - - - -		



ID EX1

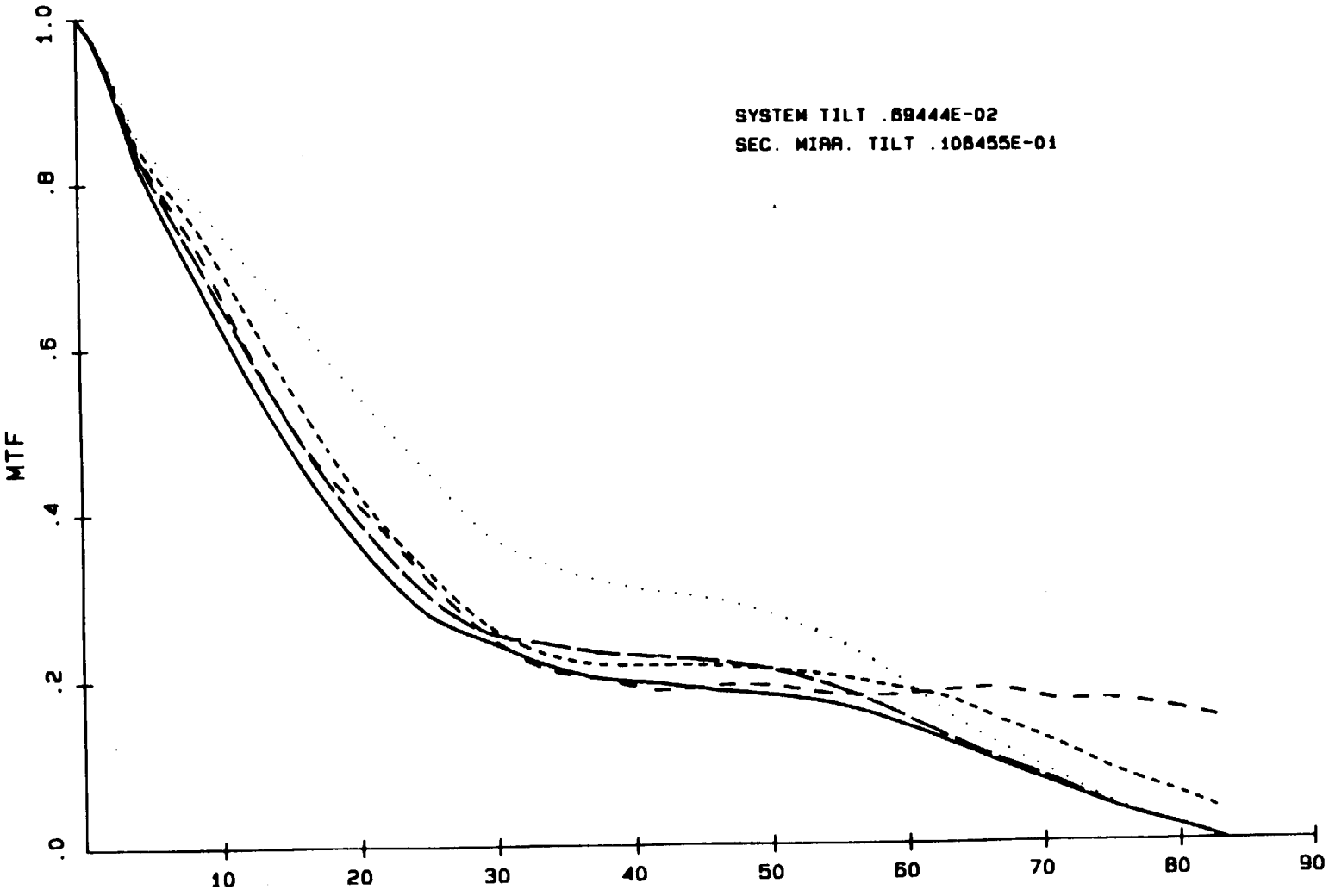
1147

DEFOCUS -3.036473

SEMI APERTURE = 152.4000 MM

MODULATION TRANSFER FUNCTION

DIFF. LIM.	.0000 FIELD	1.0000 FIELD	WAVELENGTH	WEIGHT
TAN.	———	— — —	.52502	1.000
SAG.	——— ———	- - - - - -		



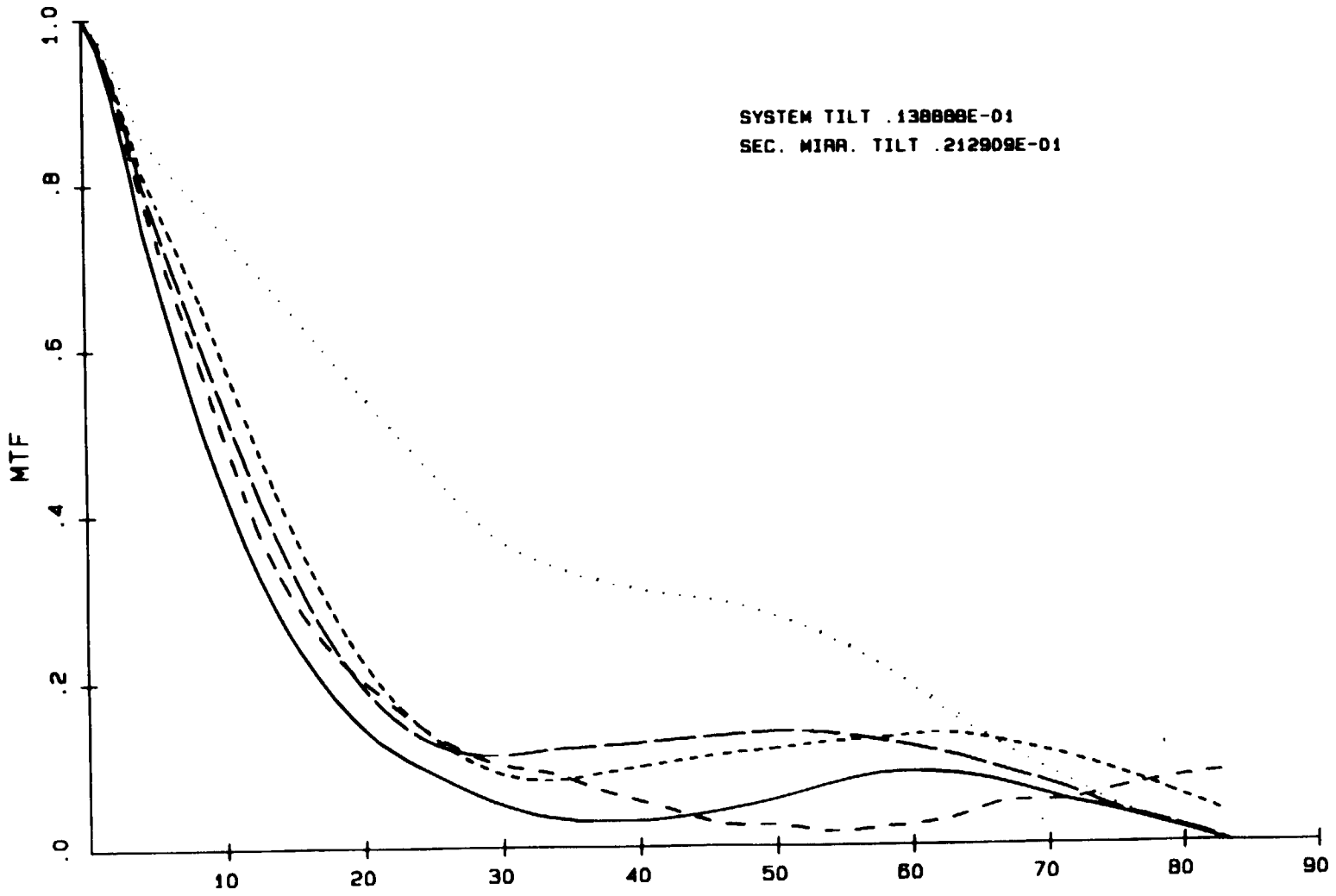
ID EXBVMF1

1147

DEFOCUS -.147509

MODULATION TRANSFER FUNCTION

DIFF. LIM.	.0000 FIELD	1.0000 FIELD	WAVELENGTH	WEIGHT
TAN.	———	— — —	.52502	1.000
SAG.	——— ———	- - - - - -		



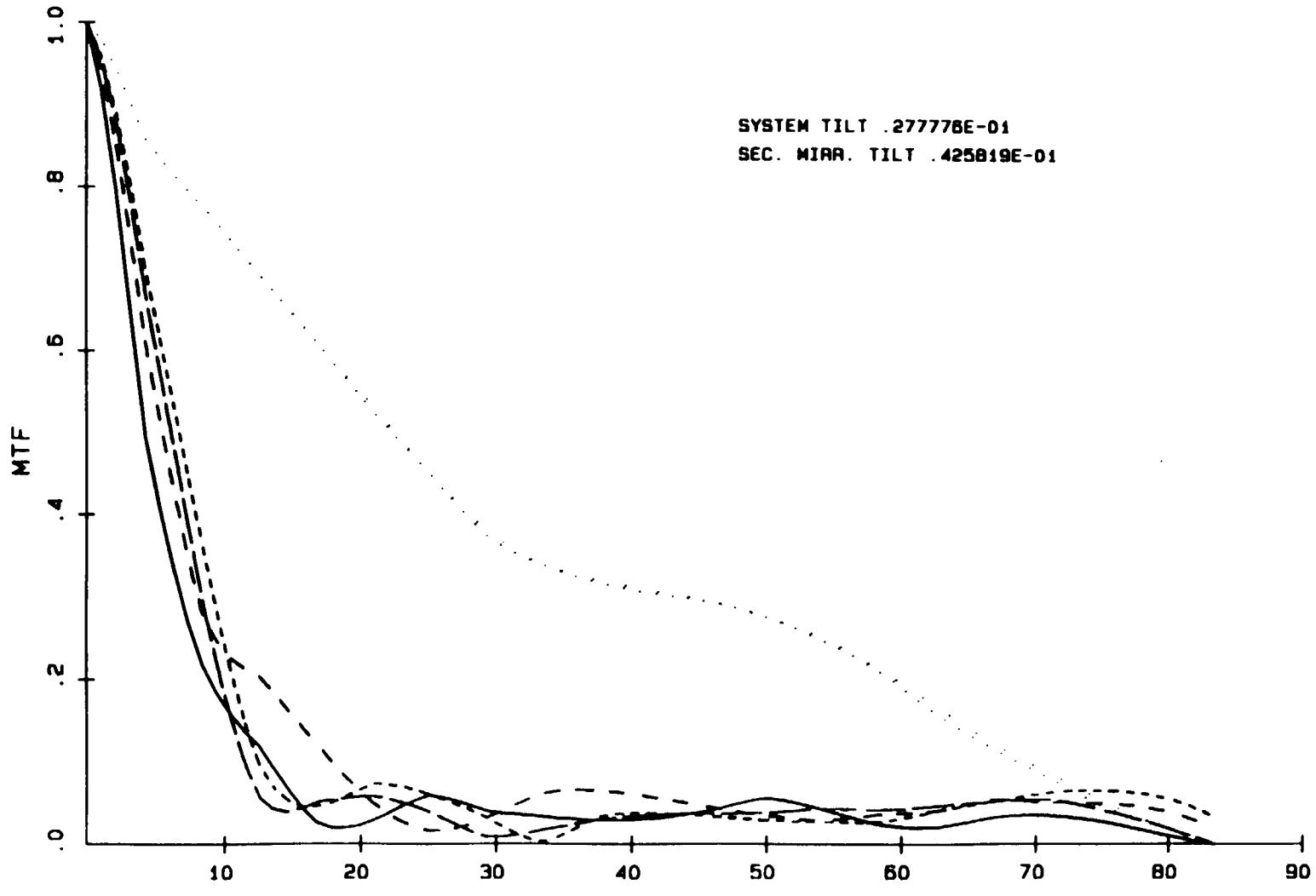
ID EXBVMF1

1147

DEFOCUS -.147509

MODULATION TRANSFER FUNCTION

DIFF. LIM.		.0000 FIELD	1.0000 FIELD	WAVELENGTH WEIGHT
TAN.	.....	———	— — —	.52502 1.000
SAG.	.....	——— ———	- - - - - -	



ID EXBVMF1 1147 DEFOCUS -.147509

SEMI-FIELD = .0800 DEGREES SEMI-APERTURE = 304.8000 MM